HUC 10290110 – Niangua
Water body ID#: 1170 and 1180
Pollutant(s): Pathogens as indicated by *Escherichia coli*

MISSOURI NATURAL RESOURCES

WATER PROTECTION PROGRAM

Total Maximum Daily Load (TMDL)

for

Upper Niangua River Watershed

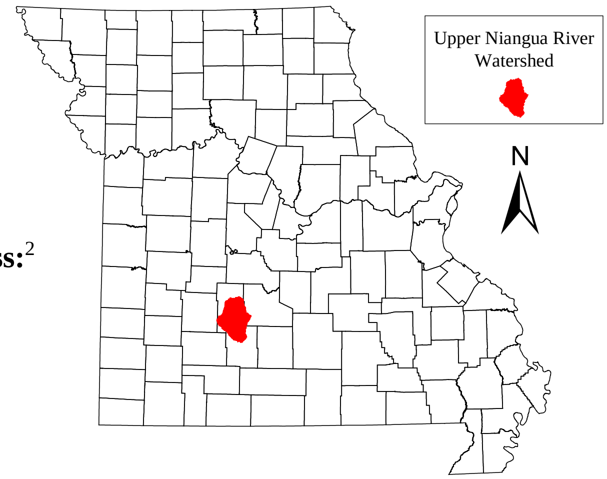
Dallas and Webster counties

Pollutants of concern: Pathogens

Submitted: Nov. 9, 2017
Approved: Jan. 16, 2018

Prepared by: Watershed Protection Section

WATER BODY SUMMARY
Total Maximum Daily Loads (TMDLs) for the Upper Niangua River Watershed
Pollutant(s): Pathogens as indicated by *E. coli*



Names: Niangua River and Dousinbury Creek

Location: Dallas and Webster counties

8-digit Hydrologic Unit Code (HUC):[1]
HUC 10290110 – Niangua subbasin

Water Body Identification Number and Hydrologic Class:[2]
1170 – Niangua River – Class P
1180 – Dousinbury Creek – Class P

Designated Uses:[3]
Irrigation
Livestock and wildlife protection
Human health protection
Protection and propagation of fish, shellfish and wildlife – cool water habitat (Niangua River)
Protection and propagation of fish, shellfish and wildlife – warm water habitat (Dousinbury Creek)
Whole body contact recreation category A (Niangua River)
Whole body contact recreation category B (Dousinbury Creek)
Secondary contact recreation

Impaired Uses:
Whole body contact recreation categories A and B

Pollutant Identified on the 303(d) List:
Escherichia coli or *E. coli* (fecal indicator bacteria)

Length and Location of Impaired Segment:
Niangua River – 90 kilometers (56 miles) from Bennett Spring Creek to Sec. 33, T32N, R18W
Dousinbury Creek – 6 km (3.9 mi) from mouth to Sec. 17, T33N, R18W

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[1] Watersheds are delineated by the U.S. Geological Survey using a nationwide system based on surface hydrologic features. This system divides the country into 2,270 8-digit hydrologic units (USGS and NRCS 2013). A hydrologic unit is a drainage area delineated to nest in a multilevel, hierarchical drainage system. A hydrologic unit code is the numerical identifier of a specific hydrologic unit consisting of a 2-digit sequence for each specific level within the delineation hierarchy (FGDC 2003).

[2] For hydrologic classes see 10 CSR 20-7.031(1)(F). Class P streams maintain permanent flow even in drought periods.

[3] For designated uses see 10 CSR 20-7.031(1)(C) and 10 CSR 20-7.031 Table H. Presumed uses are assigned per 10 CSR 20-7.031(2)(A) and (B) and are reflected in the Missouri Use Designation Dataset described at 10 CSR 20-7.031(2)(E).

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1. Introduction

The Department of Natural Resources in accordance with Section 303(d) of the federal Clean Water Act is establishing this Upper Niangua River watershed total maximum daily load, or TMDL. This TMDL report includes two water body segments that were approved by the U.S. Environmental Protection Agency for inclusion on Missouri's 2016 303(d) List of impaired waters on July 12, 2016. These streams have been determined to be impaired by disease causing pathogens as indicated by the presence of *Escherichia coli*, or *E. coli*, bacteria, which occur at concentrations that exceed Missouri's water quality criteria for this pollutant. This report addresses the pathogen impairments in the Niangua River watershed by establishing TMDLs for *E. coli*.

Section 303(d) of the federal Clean Water Act and Chapter 40 of the Code of Federal Regulations (CFR) Part 130 requires states to develop TMDLs for waters not meeting applicable water quality standards. The purpose of a TMDL is to determine the pollutant loading a water body can assimilate without exceeding state water quality standards. Missouri's Water Quality Standards at 10 CSR 20-7.031 consist of three major components: designated uses, water quality criteria to protect those uses and an antidegradation policy. A TMDL establishes the pollutant loading capacity of a water body that if met and not exceeded will result in attainment of water quality standards. A TMDL consists of a wasteload allocation, a load allocation, and a margin of safety. The wasteload allocation is the fraction of the total pollutant load apportioned to point sources. The load allocation is the fraction of the total pollutant load apportioned to nonpoint sources. The margin of safety is a percentage of the TMDL that accounts for any uncertainty associated with modeling assumptions and data inadequacies.

The Niangua River and its tributary Dousinbury Creek were first listed as impaired in 2006 for not attaining recreational uses due to elevated *E. coli* concentrations. According to the department's 2016 Listing Methodology Document, a water body is determined to be impaired by pathogens if the geometric mean of measured *E. coli* in a given recreational season exceeds the water quality criterion in any of the last three years in which there were at least five samples. The recreational season extends from April 1 through October 31. The department maintains current and past 303(d) lists and corresponding assessment worksheets online at dnr.mo.gov/env/wpp/waterquality/303d/303d.htm.

2. Watershed Description

The Upper Niangua River watershed is located in southwest Missouri within the Niangua subbasin, which is cataloged by the U.S. Geological Survey as the 8-digit HUC 10290110. For the purposes of this TMDL, the Upper Niangua River watershed includes the entire 10-digit HUC 1029011001 and the 12-digit HUC 102901100203. The Upper Niangua River watershed is approximately 1,026 square kilometers (396 square miles) and includes portions of the municipalities of Bennett Springs, Buffalo, Conway, Marshfield, Niangua and Phillipsburg. The impaired portion of the Niangua River that is addressed by this TMDL extends 90 km (56 mi) from the confluence with Bennett Spring Creek at Bennett Spring State Park to the confluence with East Fork Niangua River near Black Horse Road. Dousinbury Creek is impaired from its confluence with the Niangua River to about 900 feet west of Dousinbury Road, approximately 6 km (3.9 mi). The Dousinbury Creek subwatershed includes the entire 12-digit HUC 102901100104, which drains approximately 109 km^2 (42 mi^2). A map of the Upper Niangua River watershed showing locations of the impaired water body segments is presented in Figure 1.

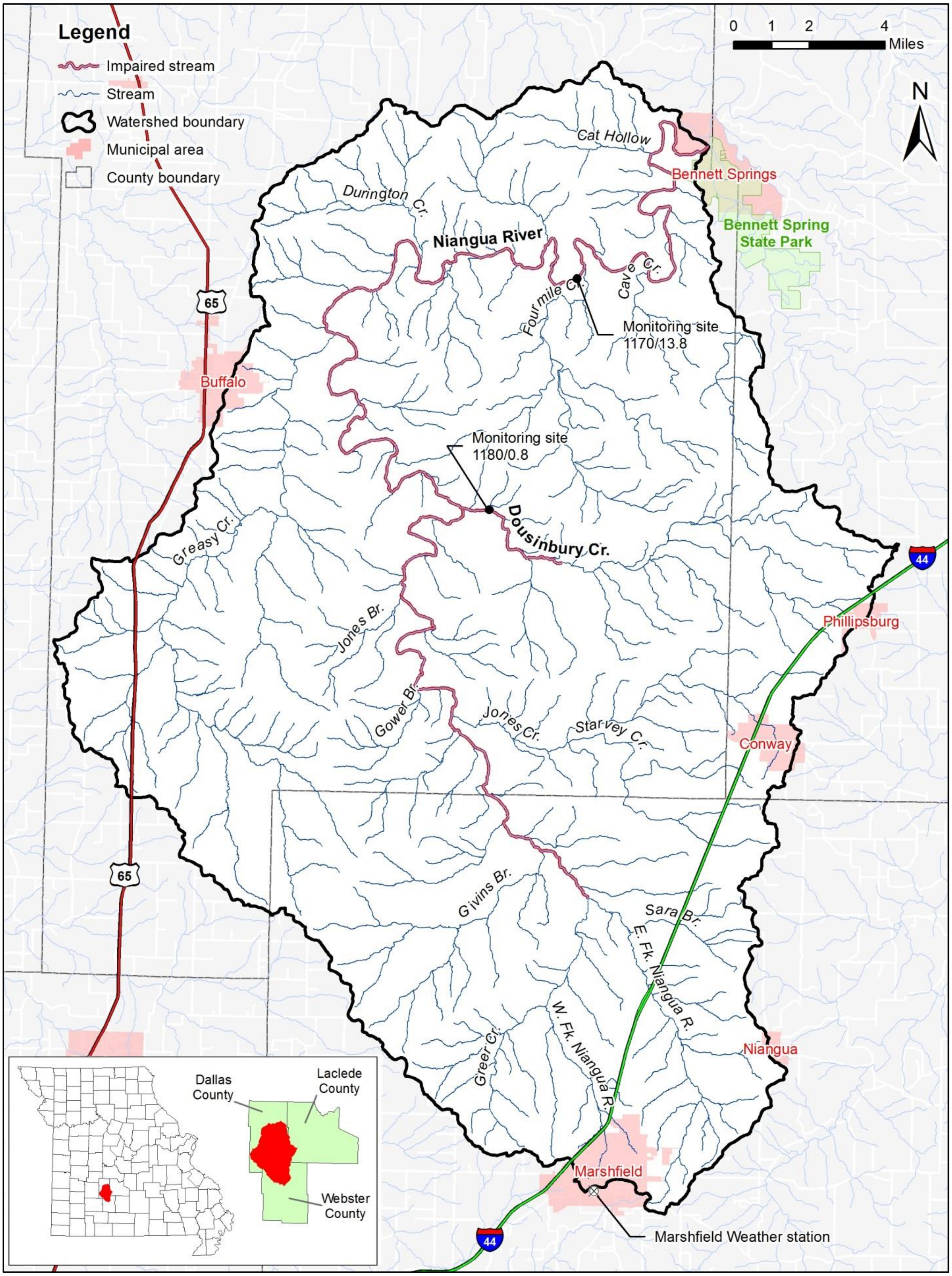

Figure 1. The Upper Niangua River watershed

2.1 Geology, Physiography and Soils

The Upper Niangua River Watershed is located within the Osage ecological drainage unit (MoRAP 2005). Ecological drainage units are groups of watersheds that have similar biota, geography, and climate characteristics (USGS 2009). The characteristics of an ecological drainage unit are varied and are partially based on the ecoregions they contain. Ecoregions are areas with similar ecosystems and environmental resources.[4] The Upper Niangua River Watershed lies within portions of two level IV ecoregions, but approximately 95 percent of the total area is located within the Central Plateau ecoregion and only 5 percent just upstream of Bennett Spring State Park is in the Osage/Gasconade Hills ecoregion (Figure 2). The Central Plateau ecoregion is composed of numerous small plateaus cut by the streams in the region. Other defining characteristic of the Central Plateau are prairie vegetation, cherty soils, and numerous karst features (Chapman et al. 2002). Karst features in this portion of the Upper Niangua River Watershed include six losing streams, 33 known sinkholes, and 29 identified springs. The remaining 5 percent of the watershed, which includes the last 27 km (17 mi) of the downstream end of the impaired segment of the Niangua River, is located within the Osage/Gasconade Hills ecoregion. This ecoregion is defined as being primarily forested with rocky soils. Karst features are common in this ecoregion as well (Chapman et al. 2002).

Soils in the Upper Niangua River watershed are varied, but are grouped based on similar characteristics. Hydrologic soil groups categorize soils by their runoff potential and relate to the rate at which water enters the soil profile under conditions of a bare soil surface being thoroughly wetted. Group A represents soils with the highest rate of infiltration and the lowest runoff potential under these conditions and Group D represents the group with the lowest rate of infiltration and highest potential for runoff (NRCS 2007). Dual groups (e.g. C/D) share the soil characteristics of its primary group, but also have a high water table as found in Group D soils. Areas where soils were not rated are primarily areas described in the soil survey as being open water or pits and quarries. It should be noted that hydrologic soil groups are only one factor influencing runoff in the watershed. Impervious surfaces, vegetative cover, slope, rainfall intensity and land use can significantly influence the potential for runoff despite the hydrologic soil groups present. Hydrologic soil group data for the Upper Niangua River watershed are summarized in Table 1. A map showing the distribution of these soil groups throughout the watershed is presented in Figure 3.

Table 1. Hydrologic soil groups in the Upper Niangua River watershed (NRCS 2011)

Hydrologic Soil Group	***Area (km^2)***	***Area (mi^2)***	***Area (%)***
Group A	5.69	2.2	0.6
Group B	282.83	109.2	27.5
Group C	356.38	137.6	34.7
Dual Group C/D	88.32	34.1	8.6
Group D	292.41	112.9	28.5
Not Rated	1.04	0.4	0.1
Totals:	1,026.67	396.4	100.0

[4] Missouri's Water Quality Standards define the term ecoregion at 10 CSR 20-7.031 (1)(I).

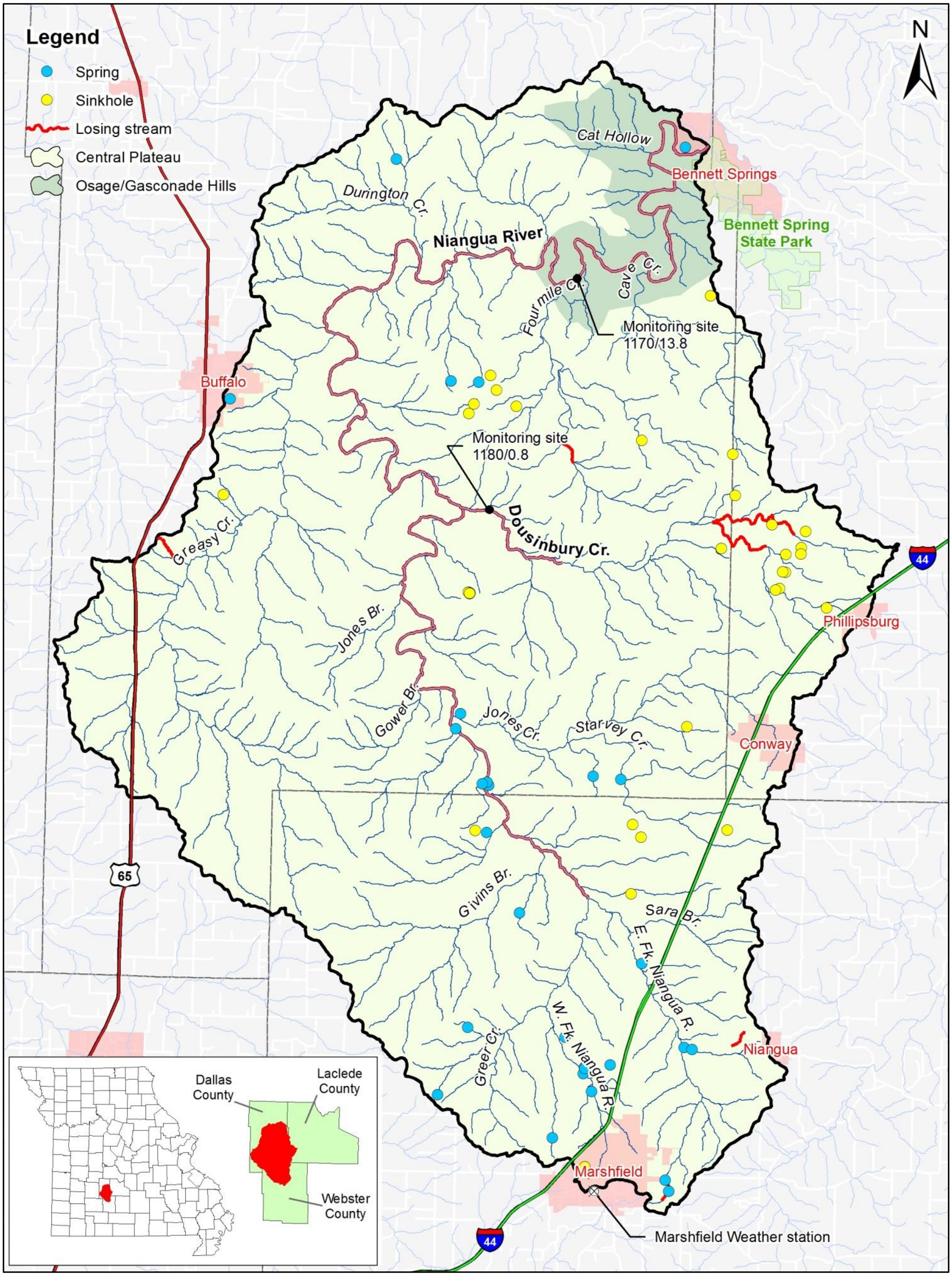

Figure 2. Level IV ecoregions and karst features in the Upper Niangua River watershed

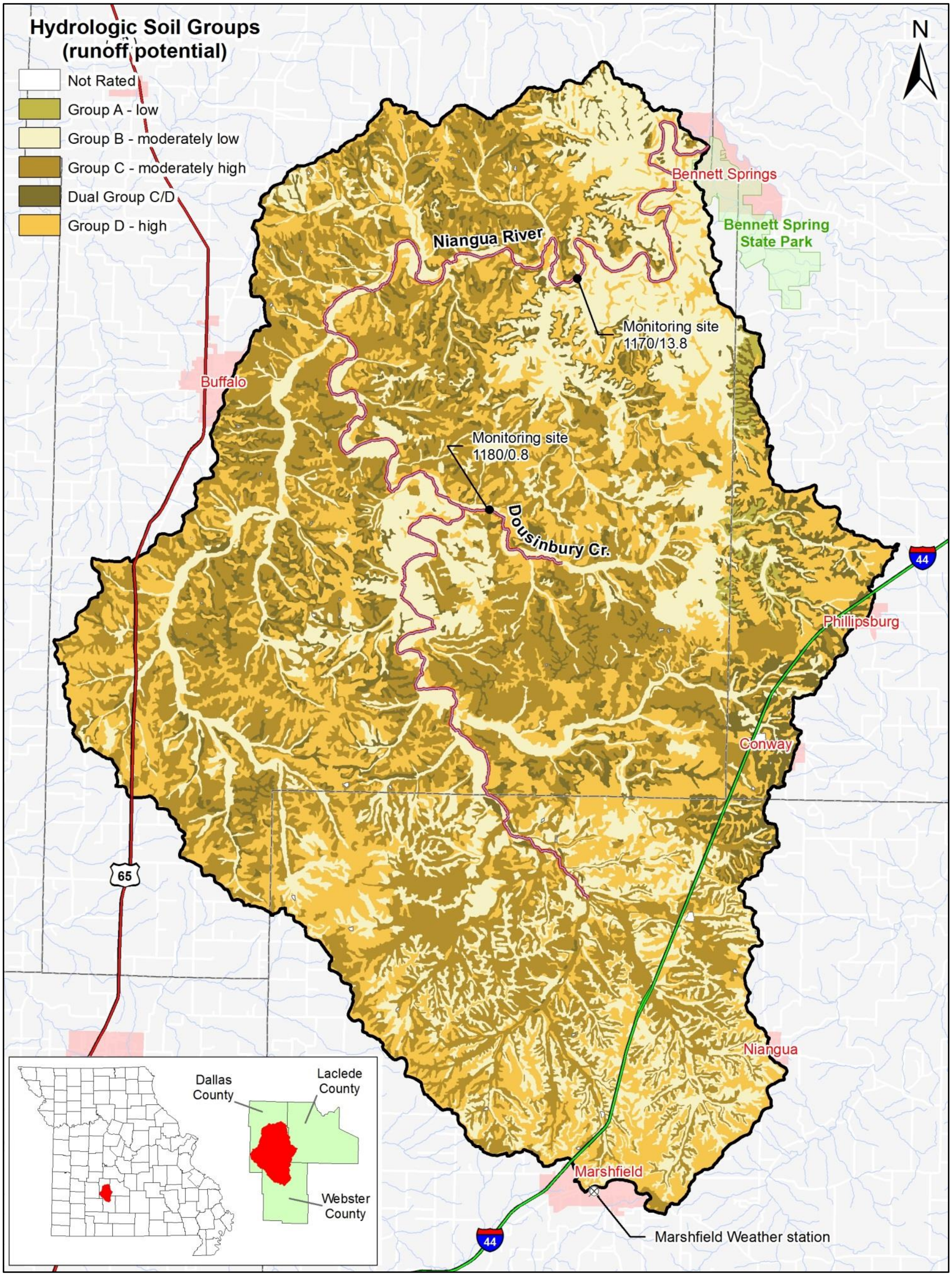

Figure 3. Hydrologic soil groups in the Upper Niangua River watershed

2.2 Climate

Weather stations provide useful information for developing a general understanding of climatic conditions in a watershed. The most recent climate data from a weather station in close proximity to the Upper Niangua River watershed comes from the Marshfield weather station and are derived from weather data collected during the 30-year period of 1981 through 2010. The monthly precipitation and temperature normals calculated using daily weather data from this station are representative of the climatic conditions in the Upper Niangua River watershed. Of the various climatic factors, precipitation is especially important as it is related to stream flow and runoff events that can influence certain pollutant sources. Table 2 presents the 30-year monthly climate normals from the Marshfield weather station for both temperature and precipitation.[5] Figures 4 and 5 further summarize these data.

Table 2. 30-year monthly climate normals at the Marshfield weather station (NOAA 2016)

Month	*Total PPTN Normal mm (in)*	*Mean Max Temp. Normal ºC (ºF)*	*Mean Min Temp. Normal ºC (ºF)*
January	67.0 (2.64)	5.4 (41.8)	-6.4 (20.4)
February	61.4 (2.42)	8.2 (46.8)	-4.2 (24.3)
March	91.6 (3.61)	13.7 (56.7)	0.6 (33.2)
April	105.6 (4.16)	19.2 (66.7)	6.0 (42.9)
May	129.7 (5.11)	23.8 (74.9)	11.9 (53.5)
June	115.8 (4.56)	28.1 (82.7)	16.6 (61.9)
July	101.3 (3.99)	30.7 (87.3)	19.2 (66.7)
August	76.2 (3.00)	30.8 (87.6)	18.7 (65.7)
September	108.7 (4.28)	26.1 (79.0)	13.7 (56.7)
October	93.4 (3.68)	20.0 (68.0)	7.5 (45.5)
November	106.4 (4.19)	13.2 (55.9)	1.2 (34.3)
December	79.2 (3.12)	6.6 (44.0)	-4.5 (23.8)
Total PPTN & Avg Temp:	1,136.3 (44.76)	18.8 (66.0)	6.7 (44.1)

Note: PPTN = precipitation; Temp. = temperature

[5] Climate normals are three-decade averages of climatological variables, including temperature and precipitation, produced by the National Centers for Environmental Information every 10 years (NOAA 2016).

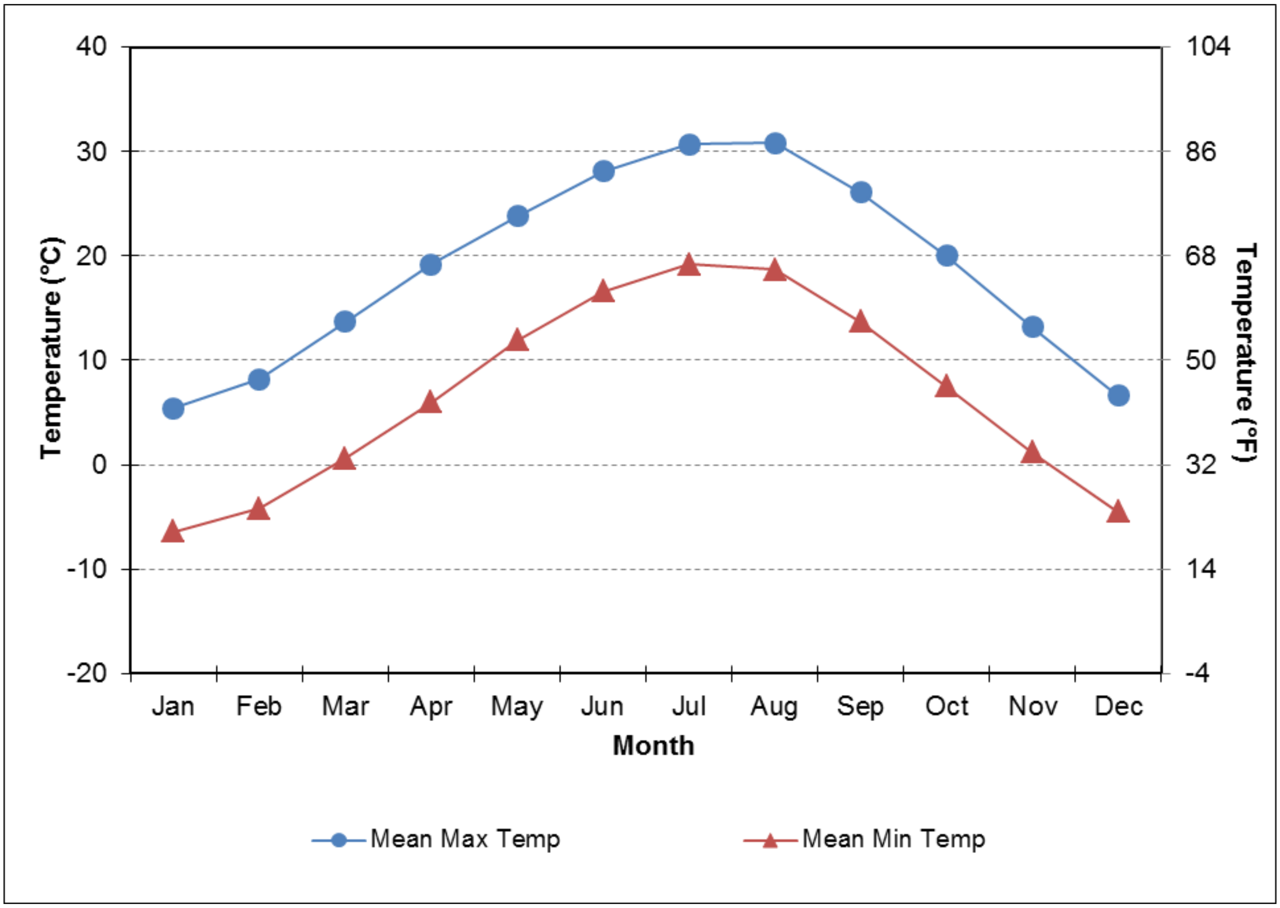

Figure 4. Monthly minimum and maximum temperature normals – Marshfield Weather Station

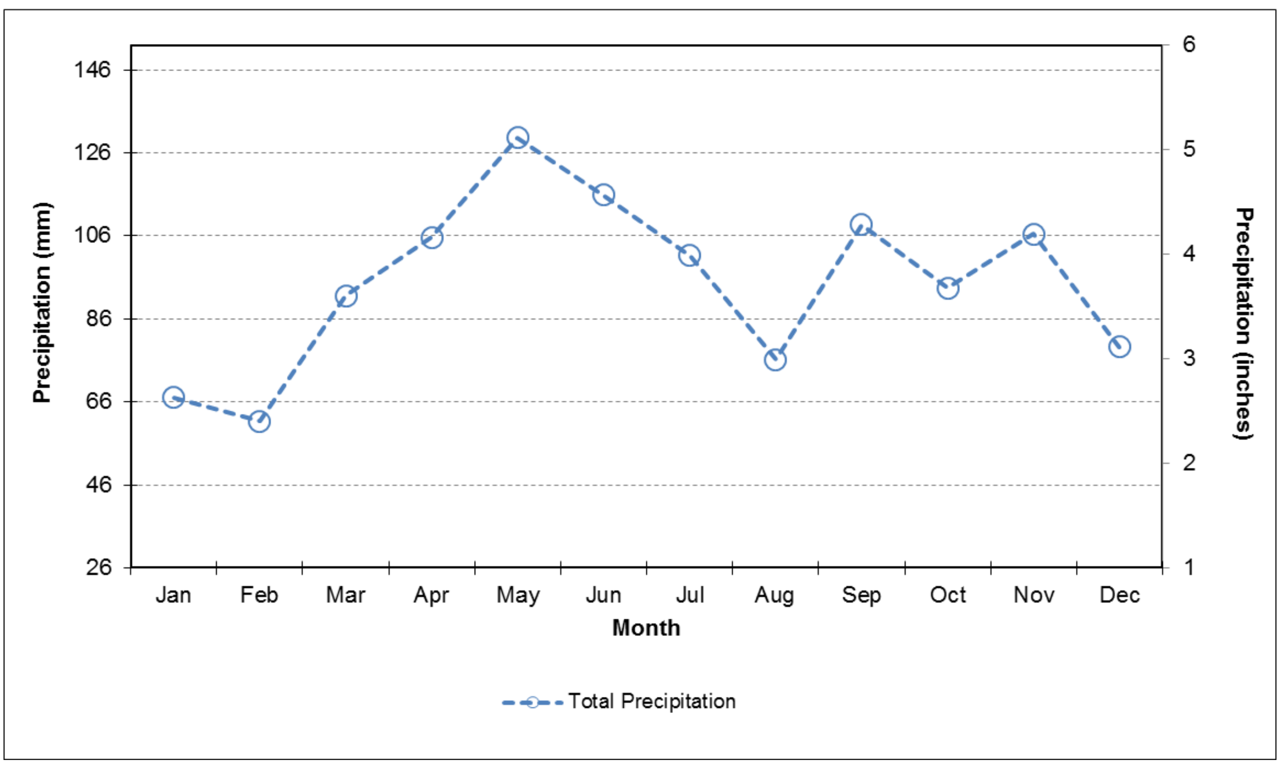

Figure 5. Monthly precipitation normals – Marshfield Weather Station

2.3 Population

State and county population estimates are readily available from the U.S. Census Bureau's 2010 census. The population of the Upper Niangua River watershed itself is not. An estimate of the watershed's population can be determined using U.S. Census Bureau census block data from 2010. Table 3 provides a summary of population estimates for the Upper Niangua River watershed. As of the 2010 census, the U.S. Census Bureau has not classified any portions of the watershed as being an "urban area." Such a designation is one criterion used for determining if a municipality is subject to small municipal separate storm sewer system permit regulations. At the time of this writing, no entities in the Upper Niangua River watershed are subject to such regulations.

These population estimates were derived using Geographic Information System, or GIS, software and superimposing the watershed boundary over a map of census blocks. Wherever the centroid of a census block fell within a watershed boundary, the entire population of the census block was included in the total. If the centroid of the census block was outside the boundary, then the population of the entire block was excluded. Using a similar method, the urban population was estimated by superimposing municipal areas over the map of census blocks. The rural population was calculated as the difference of the urban population from the total population.

Table 3. Population estimates for the Upper Niangua River watershed

Location	***Urban Population***			***Rural Population***			***Total Population***		
	1990	**2000**	**2010**	**1990**	**2000**	**2010**	**1990**	**2000**	**2010**
Entire Watershed	4,186	5,008	5,514	8,509	10,940	12,021	12,695	15,948	17,535
Dousinbury Creek Subwatershed	124	140	157	478	569	529	602	709	686

EPA completed a separate population analysis for purposes unrelated to this TMDL. They used demographic and census block data and a web-based tool called EJSCREEN to determine areas of the state having potential Environmental Justice concerns. EPA defines Environmental Justice as the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations and policies (EPA 2014b). Environmental Justice communities may qualify for financial and strategic assistance for addressing environmental and public health issues (EPA 2011a). From this analysis, the 12-digit HUC subwatersheds having potential Environmental Justice concerns are listed in Table 4.

Table 4. 12-digit HUCs with potential Environmental Justice concerns

12-Digit HUC	***HUC Name***	***Percent EJ area***
102901100101	Headwaters Niangua River	0 – 5 %
102901100107	Greasy Creek	5 – 15 %
102901100108	Benton Branch-Niangua River	0 – 5 %
102901100110	Durington Creek-Niangua River	0 – 5 %

2.4 Land Cover

A land cover analysis was completed using the 2011 National Land Cover Database published by the U.S. Geological Survey, or USGS (Homer et al. 2015). Land cover information for the entire watershed is summarized in Table 5 and calculations specific to the Dousinbury Creek subwatershed are summarized in Table 6. Figure 6 depicts the distribution and type of land coverage throughout the entire Upper Niangua River watershed. As shown, the dominant land coverages in the watershed are forest and pasturelands.

Table 5. Land Cover in the Upper Niangua River watershed

Land Cover Type	Area hectare (acre)	Area km^2 (mi^2)	Percent (%)
Developed, High Intensity	41.2 (102)	0.41 (0.16)	0.04
Developed, Medium Intensity	211.2 (522)	2.12 (0.82)	0.21
Developed, Low Intensity	1,032.7 (2,552)	10.33 (3.99)	1.01
Developed, Open Space	4,473.8 (11,055)	44.72 (17.27)	4.35
Barren Land	134.3 (332)	1.34 (0.52)	0.13
Cultivated Crops	348.4 (861)	3.49 (1.35)	0.34
Hay/Pasture	44,220.8(109,272)	442.21 (170.74)	43.07
Forest	49,712.4 (122,842)	497.14 (191.95)	48.42
Shrub and Herbaceous	1,881.3 (4,649)	18.80 (7.26)	1.83
Wetlands	510.3 (1,261)	5.10 (1.97)	0.50
Open Water	100.7 (249)	1.01 (0.39)	0.10
Totals =	102,667.1 (253,697)	1,026.67 (396.42)	100.00

Table 6. Land Cover in the Dousinbury Creek subwatershed

Land Cover Type	Area hectare (acre)	Area km^2 (mi^2)	Percent (%)
Developed, High Intensity	1 (2)	0.01 (0.00)	0.01
Developed, Medium Intensity	10 (24)	0.10 (0.04)	0.09
Developed, Low Intensity	51 (129)	0.51 (0.20)	0.47
Developed, Open Space	401 (991)	4.01 (1.55)	3.68
Barren Land	5 (11)	0.05 (0.02)	0.05
Cultivated Crops	59 (145)	0.59 (0.23)	0.55
Hay/Pasture	4,656 (11,509)	46.56 (17.98)	42.68
Forest	5,514 (13,627)	55.14 (21.29)	50.53
Shrub and Herbaceous	181 (450)	1.81 (0.70)	1.66
Wetlands	23 (58)	0.23 (0.09)	0.21
Open Water	8 (21)	0.08 (0.03)	0.07
Totals =	10,909 (26,967)	109.09 (42.13)	100.00

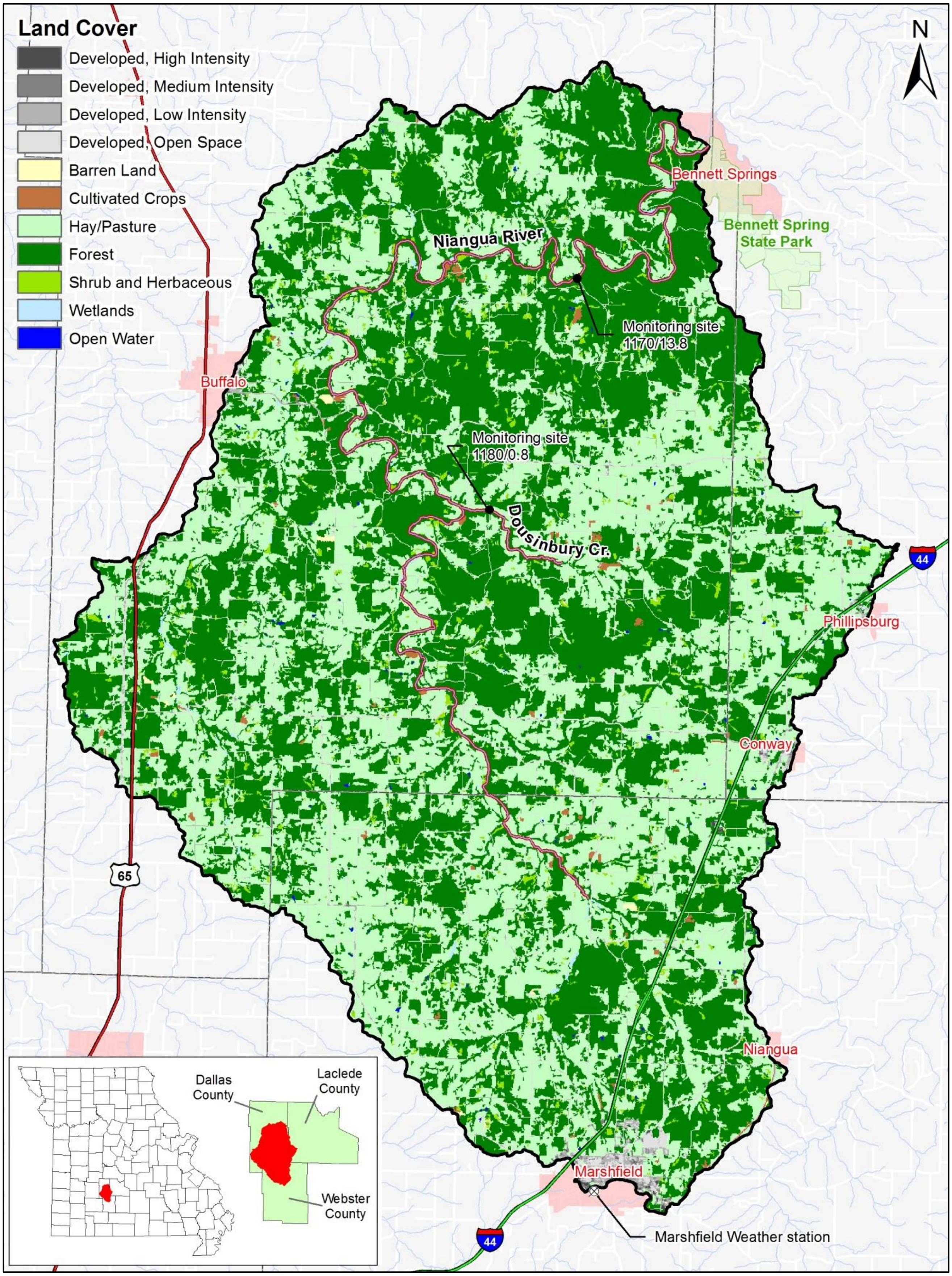

Figure 6. Land cover in the Upper Niangua River watershed

3. Applicable Water Quality Standards

The purpose of developing a TMDL is to identify the maximum pollutant loading that a water body can assimilate and still attain and maintain water quality standards. Water quality standards are therefore central to the TMDL development process. Under the federal Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters (U.S. Code Title 33, Chapter 26, Subchapter III). Water quality standards consist of three major components: designated uses, water quality criteria, and an antidegradation policy. Per federal regulations at 40 CFR §131.10, the designated uses and criteria to protect those uses assigned to a water body shall provide for the attainment and maintenance of the water quality standards of downstream waters. The components of Missouri's Water Quality Standards discussed in this section have met these requirements and have been approved by the EPA. It is not the purview of a TMDL to revise existing water quality standards. In the event that future water quality monitoring demonstrates that water quality standards are not protective of downstream uses, the Clean Water Act provides means to address the situation. Such means are described in the EPA's Water Quality Handbook.[6]

3.1 Designated Uses

Designated uses are the uses for a water body defined in the Missouri's Water Quality Standards at 10 CSR 20-7.031(1)(C) and assigned per 10 CSR 20-7.031(2) and Table H.[7] These uses must be maintained in accordance with the federal Clean Water Act. The following designated uses have been assigned to the impaired waterbodies and are reflected in the Missouri Use Designation Dataset as described at 10 CSR 20-7.031(2)(E):[8]

- Irrigation
- Livestock and wildlife protection
- Human health protection
- Protection and propagation of fish, shellfish and wildlife
    - Cool water habitat – Niangua River
    - Warm water habitat – Dousinbury Creek
- Whole body contact recreation
    - Category A – Niangua River
    - Category B – Dousinbury Creek
- Secondary Contact Recreation

The designated uses that are impaired due to high *E. coli* concentrations are whole body contact recreation categories A and B. Whole body contact recreation includes activities in which there is direct human contact with surface water that results in complete body submergence, such as swimming. During such activities, accidental ingestion of the water may occur and there is direct contact to sensitive body organs, such as the eyes, ears and nose. Category A waters include water bodies that have been established by the property owner as public swimming areas welcoming access by the public for swimming purposes and waters with documented existing whole body contact recreation uses by the public (10 CSR 20-7.031(1)(C)2.A.(I)). Category B applies to waters designated for whole body contact recreation, but are not contained within category A (10 CSR 20-7.031(1)(C)2.A.(II)). Secondary contact recreation, which includes activities such as boating, fishing

[6] https://www.epa.gov/wqs-tech/water-quality-standards-handbook

[7] The terminology used for naming designated uses varies from what is presented in the text of 10 CSR 20-7.031 and what is presented in Table H. The terminology utilized in the text of the water quality standards rule is presented here.

[8] The Missouri Use Designation Dataset documents the names and locations of the state's rivers, streams, lakes and reservoirs, which have been assigned designated uses (10 CSR 20-7.031 (1)(P)).

and wading, is not impaired. Secondary contact recreation includes activities in which there is limited, incidental or accidental contact with the water and the probability of ingesting appreciable quantities of water is minimal (10 CSR 20-7.031(1)(C)2.B.).

3.2 Water Quality Criteria

Water quality criteria are limits on certain chemicals or conditions in a water body to protect particular designated uses. Water quality criteria can be expressed as specific numeric criteria or as general narrative statements. In Missouri's Water Quality Standards at 10 CSR 20-7.031(5)(C) and Table A, specific numeric *E. coli* criteria are given to protect whole body contact recreation. *E. coli* are bacteria found in the intestines of humans and warm-blooded animals and are used as indicators of potential fecal contamination and risk of pathogen-induced illness to humans. For category A waters, the *E. coli* count during the recreational season shall not exceed the geometric mean of 126 counts/100 mL of water. For category B waters, the geometric mean shall not exceed 206 counts/100 mL of water. Both of these criteria are also protective of the secondary contact recreation designated use. The *E. coli* criterion for the protection of secondary contact recreation is a recreational season geometric mean that does not exceed 1,134 counts/100 mL of water.

3.3 Antidegradation Policy

Missouri's Water Quality Standards include the EPA "three-tiered" approach to antidegradation, and may be found at 10 CSR 20-7.031(3).

Tier 1 – Protects public health, existing instream water uses and a level of water quality necessary to maintain and protect those uses. Tier 1 provides the absolute floor of water quality for all waters of the United States. Existing instream water uses are those uses that were attained on or after Nov. 28, 1975, the date of EPA's first Water Quality Standards Regulation.

Tier 2 – Protects and maintains the existing level of water quality where it is better than applicable water quality criteria. Before water quality in Tier 2 waters can be lowered, there must be an antidegradation review consisting of: (1) a finding that it is necessary to accommodate important economic and social development in the area where the waters are located; (2) full satisfaction of all intergovernmental coordination and public participation provisions; and (3) assurance that the highest statutory and regulatory requirements for point sources and best management practices for nonpoint sources are achieved. Furthermore, water quality may not be lowered to less than the level necessary to fully protect the "fishable/swimmable" uses and other existing uses.

Tier 3 – Protects the quality of outstanding national and state resource waters, such as waters of national and state parks, wildlife refuges and waters of exceptional recreational or ecological significance. There may be no new or increased discharges to these waters and no new or increased discharges to tributaries of these waters that would result in lower water quality.

Waters in which a pollutant is at, near or exceeds the water quality criteria are considered in Tier 1 status for that pollutant. Therefore, the antidegradation goal for the impaired water body segments in the Upper Niangua River watershed is to restore water quality to levels that meet the water quality standards.

4. Defining the Problem

The department assesses a stream to be impaired for *E. coli* if the water quality criteria are exceeded in any of the last three years for which there is a minimum of five samples collected during the recreational season. This approach is detailed in the department's 2016 Listing Methodology Document, which is available online at dnr.mo.gov/env/wpp/waterquality/303d/303d.htm. Per federal regulations at 40 CFR§130.7(c)(1), TMDLs are required for all waters included on a state's approved 303(d) list.

Table 7 and Figures 7 and 8 present summaries of the available recreational season *E. coli* data used for assessing water quality in the impaired water bodies.[9] Appendix A provides the individual *E. coli* measurements. These observed data are presented to illustrate the nature of the impairment, but were not used in the calculation of TMDL targets or allocations.

Table 7. Summary of available recreational season *E. coli* data

Water Body	*Year*	*No. of samples*	*Minimum (count/100mL)*	*Maximum (count/100mL)*	*Geometric Mean (count/100mL)*
Niangua River	1994	7	10.0	1,800.0	187.3
	1995	5	9.0	720.0	82.3
	2014	7	8.4	139.6	27.4
	2015	6	19.9	261.0	101.5
	2016	5	44.8	1,299.7	174.6
Dousinbury Creek	1994	14	120.0	2,200.0	505.6
	1995	5	60.0	33,000.0	644.5
	1996	5	250.0	1,600.0	508.5
	2016	5	30.9	727.0	140.8

As noted in Table 7, the most recent data for Dousinbury Creek shows attainment of the whole body contact recreational use in that stream during the 2016 recreational season. However, these data are insufficient for assessment in accordance with the methodology earlier described. Additional *E. coli* monitoring is scheduled for the 2017 and 2018 recreational seasons (see Section 12). Should future assessments show that whole body contact recreational uses are being fully attained, then no further pollutant reductions will be necessary and the goals of this TMDL report will have been met.

[9] For data recorded from field duplicates, the average of the two values was used and counted as a single sample.

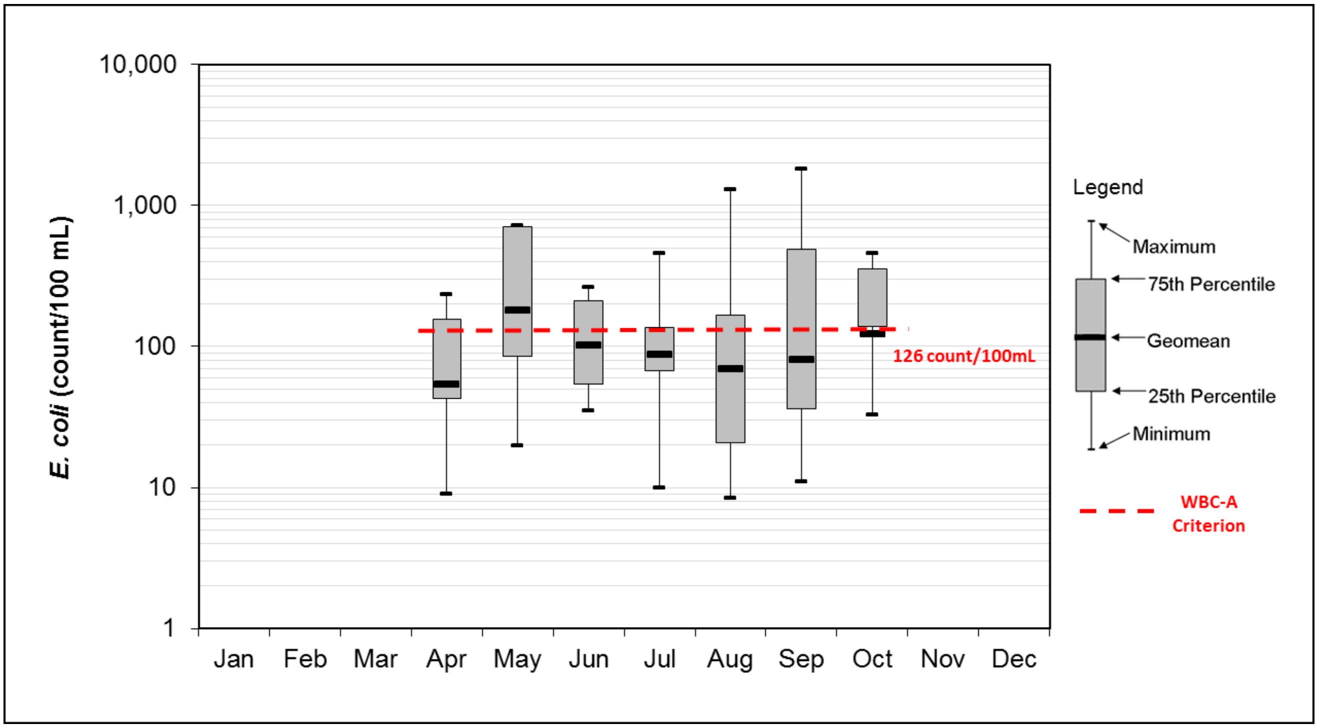

Figure 7. Monthly recreational season *E. coli* data from Niangua River

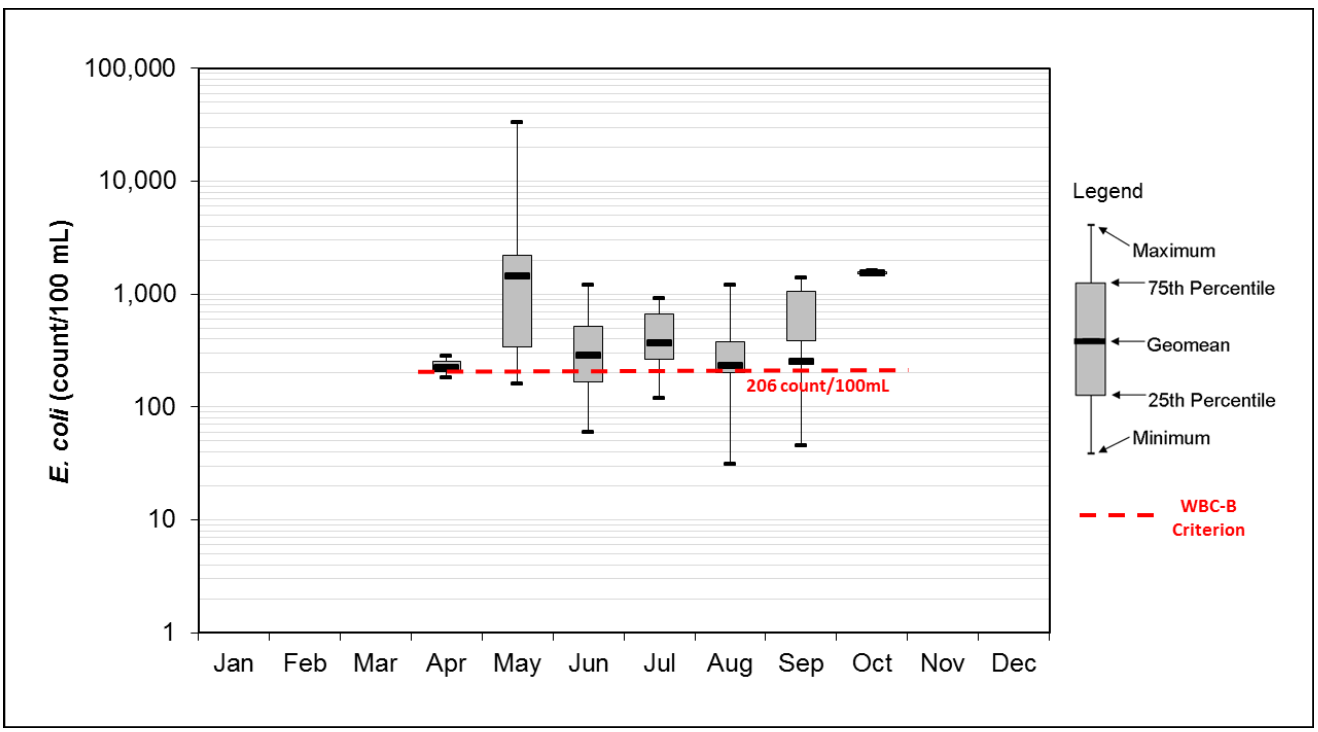

Figure 8. Monthly recreational season *E. coli* data from Dousinbury Creek

5. Source Inventory and Assessment

In the Upper Niangua River watershed, various sources may be contributing bacteria loads to the impaired water bodies. For this reason, a source inventory and assessment is included in this TMDL report to identify and characterize known, suspected and potential sources of pollutant loading to the impaired water bodies. The potential sources of bacteria in the Upper Niangua River watershed identified in this TMDL report are categorized and quantified to the extent that information is available. These sources may be point (regulated) or nonpoint (unregulated).

5.1 Point Sources

Point sources are defined under Section 502(14) of the federal Clean Water Act and are typically regulated through the Missouri State Operating Permit program.[10] Point sources include any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel or conduit, by which pollutants are transported to a water body. Under this definition, permitted point sources include permitted municipal and domestic wastewater dischargers, site-specific permitted industrial and non-domestic wastewater dischargers, concentrated animal feeding operations, municipal separate storm sewer systems, and general wastewater and stormwater permitted entites. In addition to these permitted sources, illicit straight pipe discharges, which are illegal and therefore unpermitted, are also point sources.

As of May 15, 2017, the Upper Niangua River watershed contained 36 permitted entities. None of these permitted entities are located within the Dousinbury Creek subwatershed. Eight of these permits are site-specific permits for municipal or domestic wastewater dischargers. Six of the permits are general wastewater permits, which are identified by their permit number having the prefix "MO-G" and the remaining 22 permits are general stormwater permits, which are identified by the prefix "MO-R". There are no site-specific permitted industrial and non-domestic wastewater dischargers in the watershed, nor are there any permitted animal feeding operations in the watershed. Figure 9 shows the locations of permitted outfalls in the watershed.

5.1.1 Municipal and Domestic Wastewater Discharge Permits

Dischargers of domestic wastewater include both publicly owned municipal wastewater treatment plants and non-municipal treatment facilities. Domestic wastewater is primarily household waste, including graywater and sewage. Untreated or inadequately treated discharges of domestic wastewater can be significant sources of bacteria to receiving waters (EPA 1986). Influences of pollutant loading from domestic dischargers are typically most evident at low-flow conditions when stormwater influences are lower or nonexistent. Facilities equipped with disinfection technologies are capable of discharging *E. coli* at low concentrations and should not cause or contribute to bacteria impairments.

Table 8 lists the eight domestic wastewater dischargers in the Upper Niangua River watershed. As noted in the table, five of the eight facilities currently employ either chlorine or ultraviolet disinfection as part of their treatment. The permit for the Conway wastewater treatment facility has stated *E. coli* limits protective of whole body contact recreation and includes a schedule of

[10] The Missouri State Operating system is Missouri's program for administering the federal National Pollutant Discharge Elimination System, or NPDES, program. The NPDES program requires all point sources that discharge pollutants to waters of the United States to obtain a permit. Issued and proposed operating permits are available online at dnr.mo.gov/env/wpp/permits/index.html.

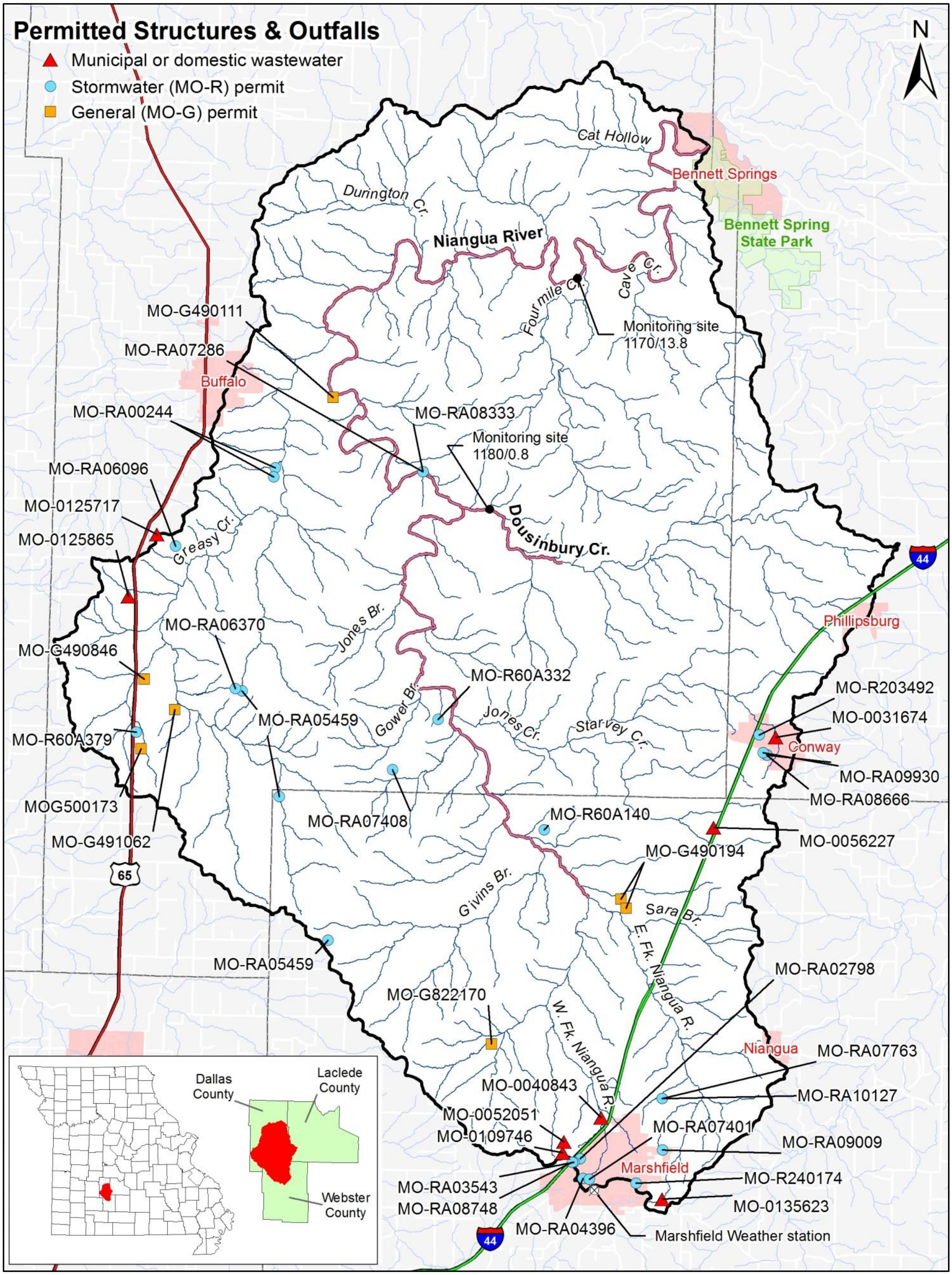

Figure 9. Permitted features in the Upper Niangua River watershed

compliance to meet these limits by 2021. Likewise, the permit for the Fountain Plaza Mobile Home Park was reissued on June 6, 2017 to include *E. coli* limits and includes a two-year schedule of compliance to meet those limits. At the time of this writing, only the permit for the Gaslight Village facility did not contain *E. coli* limits. Limits protective of the receiving water's recreational uses will be added upon renewal as will a schedule of compliance to meet those limits. Historically some facilities had been exempted from bacteria limitations and disinfection requirements due to conditions set forth in 10 CSR 20-7.015(9)(B)1.D., which only requires *E. coli* permit limitations if discharges are within two miles of a water designated for whole body contact recreation. Water quality standard revisions approved by EPA on Oct. 22, 2014, have expanded designations of whole body contact recreation to streams within two miles of all facilities within the Upper Niangua River watershed.

Table 8. Dischargers of domestic wastewater in the Upper Niangua River watershed

Facility Name*	***Permit Number***	***Design Flow m^3/s (ft^3/s)***	***Disinfection***	***Expires[11] (Mo/Day/Year)***
Conway WWTF	MO-0031674	0.0035 (0.127)	None	12/31/2018
Fountain Plaza Mobile Home Park	MO-0109746	0.0002 (0.010)	None	9/3/2017
Gaslight Village Mobile Home Park	MO-0052051	0.0001 (0.007)	None	11/8/2016
Marshfield WWTF	MO-0040843	0.0658 (2.325)	Chlorine	9/30/2018
Meritt's Campground	MO-0125865	0.0003 (0.011)	Ultraviolet	9/30/2018
MoDOT I-44 Conway Welcome Center	MO-0056227	0.0009 (0.034)	Ultraviolet	12/31/2018
Shady Lane WWTF	MO-0125717	0.0001 (0.005)	Chlorine	3/31/2015
Sho-Me Power WWTF	MO-0135623	0.0001 (0.007)	Ultraviolet	9/30/2018

* WWTF = wastewater treatment facility

In addition to direct discharges from domestic wastewater treatment facilities, potential bacteria contributions may also occur from overflows occurring from the adjoining sanitary sewer system. A sanitary sewer system is a wastewater collection system designed to convey domestic, commercial and industrial wastewater to the treatment facility. This system can include limited amounts of inflow and infiltration from groundwater and stormwater, but it is not designed to collect large amounts of runoff from precipitation events. Untreated or partially treated discharge from a sanitary sewer system is referred to as a sanitary sewer overflow. Sanitary sewer overflows can be caused by a variety of factors including blockages, line breaks, sewer defects, power failures and vandalism. Sanitary sewer overflows can occur during either dry or wet weather and at any point in the collection system including overflows from manholes or backups into private residences. These types

[11] When a permit expires, a facility remains bound by the conditions of that expired permit until either the permit is terminated or a new permit is issued.

of discharges are unauthorized by the federal Clean Water Act. Occurrences of sanitary sewer overflows can result in elevated bacteria concentrations (EPA 1996). According to data retrieved from the Missouri Clean Water Information System, or MoCWIS, both the Conway and Marshfield facilities have reported occurrences of sanitary sewer overflows. Since Jan. 1, 2012, the Conway facility has experienced nine overflows during the recreational season. The facility last reported an overflow in July 2016. During the same period, the Marshfield facility reported 34 overflows during the recreational season. To reduce overflow occurrences, the Marshfield facility has implemented a bypass elimination plan and voluntary compliance agreement. The last reported overflow from the Marshfield facility occurred in June 2015.

5.1.2 Site-Specific Industrial and Non-Domestic Wastewater Permits

Industrial and non-domestic facilities discharge wastewater resulting from non-sewage generating activities and typically are not expected to cause or contribute to bacteria impairments. At the time of this writing, there are no permitted facilities of this type in the Upper Niangua River watershed.

5.1.3 Concentrated Animal Feeding Operation (CAFO) Permits

Concentrated Animal Feeding Operations, or CAFOs, are typically animal feeding operations that confine and feed or maintain more than 1,000 animal units for 45 days or more in any 12-month period. Facilities with fewer animal units may be permitted as CAFOs voluntarily or if discharges occur or other water quality issues are discovered per 10 CSR 20-6.300. Animal wastes generated from CAFOs that are carried through stormwater runoff or by wastewater discharges can be a source of bacteria to water bodies (Rogers and Haines 2005). At the time of this writing, there are no permitted facilities of this type in the Upper Niangua River watershed.

5.1.4 Municipal Separate Storm Sewer System (MS4) Permits

A municipal separate storm sewer system, or MS4, is a stormwater conveyance system owned by a public entity that is not a combined sewer or part of a sewage treatment plant. Federal regulations issued in 1990 require discharges from such systems to be regulated by permits if a municipality's, or in some cases a county's, population is 100,000 or more. In 1999, federal regulations were issued that also require permits for discharges from small MS4s that are located within a U.S. Census Bureau defined urban area or have otherwise been designated as needing a permit by the permitting authority. At the time of this writing, there are no permitted entities of this type in the Upper Niangua River watershed.

5.1.5 General Wastewater and Non-MS4 Stormwater Permits

General and stormwater permits are issued based on the type of activity occurring and are meant to be flexible enough to allow for ease and speed of issuance, while providing the required protection of water quality. General and stormwater permits are issued to activities similar enough to be covered by a single set of requirements, and are designated with permit numbers beginning with "MO-G" or "MO-R" respectively. A list of the general and stormwater permitted entities in the Upper Niangua River watershed as of May 15, 2017, is presented in Table 9. Permits associated with construction or land disturbance activities (MO-RA) are temporary and the number of effective permits of this type may vary widely in any given year. Despite this variability, final TMDL targets and allocations will not vary as a result of any changes in the numbers of these types of permits.

Table 9. General (MO-G) and stormwater (MO-R) permitted facilities

Permit No.	*Facility Name*	*Type*	*Expiration Date*
MO-G490111	Ash Grove Aggregates-#493 Buffalo Quarry	Limestone quarry	10/5/2016
MO-G490194	AGG-#496 Marshfield Quarry	Limestone quarry	10/5/2016
MO-G490846	Hostetler Quarry, LLC	Limestone quarry	10/5/2016
MO-G491062	AGG-#466 Highway 38 Quarry	Limestone quarry	10/5/2016
MO-G500173	4-E Sand and Gravel	Sand and gravel washing	5/31/2015
MO-G822170	Horrmann Meat Company	Food processing land application	6/16/2016
MO-R203492	Conway Steel and Equipment	Light industrial metal fabrication	8/31/2019
MO-R240174	MFA Agri Service B/P - Marshfield	Agrichemical facility	4/30/2019
MO-R60A140	2-Cylinder Plus Tractor Salvage	Motor vehicle salvage	10/31/2018
MO-R60A332	Thomas Sawyer Property	Motor vehicle salvage	10/31/2018
MO-R60A379	Dallas County Recycling	Motor vehicle salvage	10/31/2018
MO-RA00244	Headings Farm	Construction or land disturbance	2/7/2017
MO-RA02798	Churchill Apartments - Marshfield	Construction or land disturbance	2/7/2017
MO-RA03543	Marshfield VA Clinic	Construction or land disturbance	2/7/2017
MO-RA04396	Metropolitan National Bank	Construction or land disturbance	2/7/2017
MO-RA05459	Crossway to March Transmission Line	Construction or land disturbance	2/7/2017
MO-RA06096	Headings Farm	Construction or land disturbance	2/7/2017
MO-RA06370	March Substation	Construction or land disturbance	2/7/2017
MO-RA07286	Enbridge Line 51 MP 243 Replacement	Construction or land disturbance	2/7/2017
MO-RA07401	Marshfield, Mo. - Dollar General	Construction or land disturbance	2/7/2017
MO-RA07408	Daniel Messenger Layer Farm	Construction or land disturbance	2/7/2017
MO-RA07763	Marshfield #5 Substation	Construction or land disturbance	2/7/2017
MO-RA08333	Enbridge Line 51 MP 243 Replacement	Construction or land disturbance	2/7/2017
MO-RA08666	Ezard Elementary School	Construction or land disturbance	2/7/2017
MO-RA08748	Marshfield Clinic	Construction or land disturbance	2/7/2017
MO-RA09009	Marshfield #2-#5 Transmission Project	Construction or land disturbance	2/7/2017
MO-RA09930	Laclede County Facility Improvements	Construction or land disturbance	2/7/2022
MO-RA10127	Marshfield #5 Substation	Construction or land disturbance	2/7/2022

For this TMDL, the department assumes the general permitted activities described in Table 9, as well as any future generally permitted activities, will be conducted in compliance with all permitted conditions, including all monitoring and discharge limitations. Therefore, it is expected that compliance with these permits will be protective of the applicable designated recreational uses within the watershed. For these reasons, general wastewater and stormwater permits are not expected to contribute significant bacteria loads and do not cause or contribute to the water quality impairment of the Niangua River. At any time, if the department determines that the water quality of streams in the watershed is not being adequately protected, the department may require the owner or operator of the permitted site to obtain a site-specific operating permit per 10 CSR 20-6.010(13)(C).

5.1.6 Illicit Straight Pipe Discharges

Illicit straight pipe discharges of domestic wastewater are also potential point sources of bacteria. These types of sewage discharges bypass treatment systems, such as a septic tank or a sanitary sewer, and instead discharge directly to a stream or an adjacent land area (Brown and Pitt 2004). Although a point source, illicit straight pipe discharges are illegal and are not authorized under the Clean Water Act. At present, there are no data about the presence or number of illicit straight pipe discharges in the Upper Niangua River watershed. For this reason, it is unknown to what significance straight pipe discharges contribute bacteria loads to either the Niangua River or Dousinbury Creek. Due to the illegal nature of these discharges, any identified illicit straight pipe discharges must be eliminated.

5.2 Nonpoint Sources

Nonpoint source pollution refers to pollution coming from diffuse, non-permitted sources that typically cannot be identified as entering a water body at a single location. They include all other categories of pollution not classified as being from a point source, and are exempt from department permit regulations per state rules at 10 CSR 20-6.010(1)(B)1. These sources involve stormwater runoff and are minor or negligible under low-flow conditions. Typical nonpoint sources of pollution that have the potential to influence water quality include various sources associated with runoff from agricultural and urban lands, onsite wastewater treatment systems, natural background contributions and riparian corridor conditions.

5.2.1 Agricultural Stormwater Runoff

Stormwater runoff from lands used for agricultural purposes may be a potential source of bacteria loading to water bodies. Activities associated with agricultural land uses that may contribute pathogens to a water body include manure fertilization of croplands or pastures, and livestock production.

Stormwater runoff from either croplands or grasslands fertilized with animal manure may become potential sources of pathogens to waters due to improper application or from soil erosion. As noted in Section 2.4 of this document, cropland accounts for less than half a percent of the land coverage in the Upper Niangua River watershed. This half a percent is unlikely to contribute significant bacteria loads to the impaired water bodies compared to more common land coverage types. Areas categorized as hay or pasture account for approximately 43 percent of the watershed area. Bacteria inputs resulting from soil erosion carried through stormwater runoff can occur if application rates are too high, are made prior to inclement weather, or are made to frozen ground or other conditions in which the manure cannot be readily incorporated into the soil (Fulhage 2000). Application rates and timing vary depending upon a number of factors, including manure quality and soil need. Operations that use nutrient management plans to guide manure applications and that employ best management practices to reduce soil erosion will contribute smaller bacteria loads than those that do not.

In addition to manure spreading, livestock within the watershed may act as direct contributors of bacteria loading to streams due to manure either being deposited directly into a waterway or from being carried by runoff from either pasturelands or low density animal feeding operations that do not require a CAFO permit. Although grazing areas are typically well vegetated, livestock tend to concentrate near feeding and watering areas causing those areas to become barren of plant cover, thereby increasing the possibility of erosion during a storm event (Sutton 1990). Stormwater runoff can carry manure from these areas to nearby streams. Additionally, direct manure contributions from

cattle or other livestock to a water body can potentially occur when livestock are not excluded from streams.

The number and type of livestock present in the Upper Niangua River watershed is unknown. An estimate of cattle numbers in the watershed was calculated using the available land cover data in Section 2.4 and county cattle population numbers provided in the U.S. Department of Agriculture's 2012 Census of Agriculture. From these data, a number of cattle per square mile of pastureland for each county in the watershed can be estimated. Using these derived cattle densities, the number of cattle within the Upper Niangua River watershed are estimated (Table 10). For beef cattle, the U.S. Department of Agriculture estimates that a 1,000 pound animal produces approximately 26.8 kilograms (59.1 pounds) of manure per day (USDA 1995).

Table 10. Cattle population estimates for pasture areas in the Upper Niangua River watershed[12]

County	*Cattle (No. of animals)*	*Pasture km^2 (mi^2)*	*Cattle Density No./km^2 (No./mi^2)*	*Watershed Pasture km^2 (mi^2)*	*Watershed Cattle (No. of animals)*
Dallas	49,895	569 (220)	88 (227)	266 (103)	38,800
Laclede	65,463	731 (282)	90 (232)	37 (14)	39,700
Webster	73,138	724 (280)	101 (261)	139 (54)	44,600

Other types of livestock may also be contributing bacteria loads in the Upper Niangua River watershed. Table 11 summarizes the county-level data for other livestock that are noted in the 2012 Census of Agriculture. There are no data available to estimate the number or distribution of these other animals in the Upper Niangua River watershed. Some of these livestock may be confined in lower-density animal feeding operations that may be acting as point sources, but are not permitted under department regulations.

Table 11. Other livestock in Dallas, Laclede and Webster counties

Livestock (Type)	*Dallas County (No. of animals)*	*Laclede County (No. of animals)*	*Webster County (No. of animals)*
Hogs and pigs	209	No data	5,200
Sheep and lambs	607	2,986	2,120
Goats	944	1,548	1,974
Equine	2,062	2,153	3,514
Poultry	2,989	3,022	37,022

[12] This analysis assumes all areas identified as being hay or pasture are being used for cattle grazing and that cattle are evenly distributed among those areas. Additionally, since there are no known CAFOs in these counties, the entire cattle population was assumed to be grazing on hay and pasture areas.

5.2.2 Urban Stormwater Runoff

In general, urban stormwater runoff may carry high levels of bacteria exceeding water quality criteria during and immediately after storm events (EPA 1983). *E. coli* contaminated runoff can come from both heavily paved areas and areas where soil erosion is common (Burton and Pitt 2002). Common sources of *E. coli* contamination in urban stormwater have been documented as originating from birds, dogs, cats, and rodents (Burton and Pitt 2002). Bacterial loads in urban runoff may also result from sanitary sewer overflows as described in Section 5.1.1 of this document.

In the Upper Niangua River watershed, areas of urban development account for approximately 5.6 percent of the total watershed area (Table 5). The most common developed category identified in the available land cover data is open space. Developed open space areas are described as having less than 20 percent imperviousness. Low intensity development accounts for approximately 1 percent of the watershed and is described as having 20 to 49 percent imperviousness. Due to the small amount of developed areas in the watershed, urban stormwater runoff is not expected to be a major contributor to the bacteria impairments of the Niangua River and Dousinbury Creek. As urban populations in the watershed continue to grow, as indicated in Table 3, loading contributions from these areas may increase if the amount of imperviousness in the watershed also increases. Degradation associated with imperviousness has been shown to first occur in a watershed at about 10 percent total imperviousness and to increase in severity as imperviousness increases (Arnold and Gibbons 1996; Schueler 1994). Best management practices and low impact development can help to mitigate the effects of increased development by reducing stormwater runoff and erosion.

5.2.3 Onsite Wastewater Treatment Systems

Approximately 25 percent of homes in Missouri utilize onsite wastewater treatment systems, particularly in rural areas where public sewer systems may not be available (DHSS 2016). Onsite wastewater treatment systems treat domestic wastewater and disperse it on the property where it has been generated, such as a home septic system. When properly designed and maintained, such systems perform well and should not serve as a source of contamination to surface waters. However, onsite wastewater treatment systems can fail for a variety of reasons. When these systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration), there can be adverse effects to surface water quality (Horsley & Witten 1996). Failing onsite wastewater treatment systems are sources of bacteria, which can reach nearby streams directly through surface runoff and groundwater flows, thereby contributing bacteria loads under wet or dry weather conditions. Onsite wastewater treatment systems may contribute bacteria to waterbodies directly or as component of stormwater runoff.

The exact number of onsite wastewater treatment systems in the Upper Niangua River watershed is unknown. EPA's online input data server for the Spreadsheet Tool for Estimating Pollutant Load, or STEPL, provides estimates of septic system numbers by 12-digit HUC watersheds based on 1992 and 1998 data from the National Environmental Service Center.[13] These STEPL derived estimates of septic system numbers are provided in Table 12. Due to continued population growth in rural areas of the watershed since the time these septic system data were collected, actual septic system numbers may be much higher. Using an estimated population of 2.2 people per septic system and the total

[13] The National Environmental Services Center is located at West Virginia University and maintains a clearinghouse for information related to, among other things, onsite wastewater treatment systems. Available URL: www.nesc.wvu.edu/

rural population of the watershed as provided in Table 3 of this report, it is estimated that there may be as many as 5,464 septic systems in the Upper Niangua River watershed.[14]

Table 12 also provides statewide estimated failure rates from a study by the Electric Power Research Institute (EPRI 2000). The study suggests that in some parts of Missouri, up to 50 percent of onsite wastewater treatment systems may be failing. Due to these high failure rates, onsite wastewater treatment systems are potential sources of bacteria loading in the Upper Niangua River watershed.

Table 12. STEPL derived estimates of septic system numbers in the Upper Niangua River watershed

12-digit HUC	*Subwatershed Name*	*Number of Septic Systems*	*Population per Septic System*	*Statewide Failure Rates*
102901100101	Headwaters Niangua River	1,393	3	30% – 50%
102901100102	Jones Creek	462	2	
102901100103	Givins Branch-Niangua River	173	3	
102901100104	Dousinbury Creek	177	2	
102901100105	Gower Branch-Niangua River	63	2	
102901100106	Headwaters Greasy Creek	268	2	
102901100107	Greasy Creek	401	2	
102901100108	Benton Branch-Niangua River	43	2	
102901100109	Fourmile Creek	65	2	
102901100110	Durington Creek-Niangua River	54	2	
102901100203	Cave Creek-Niangua River	62	2	
	Total =	3,161		

5.2.4 Natural Background Contributions

Wildlife such as deer, waterfowl, raccoons, rodents, and other animals contribute to the natural background concentrations of *E. coli* that may be found in a water body. Such contributions may be a component of agricultural stormwater runoff, urban stormwater runoff, or runoff originating from other land coverage types as described in Table 4 of this report. Typical wildlife populations are not expected to cause or contribute to water body impairments, but large congregations of animals, such as migrating Canada geese, have been known to contribute significant bacteria loads in some waters during times of the year when those animals are present in large numbers (Ishii et al. 2007). Watershed specific information is lacking, but the Missouri Department of Conservation estimates the statewide resident Canada goose population to be approximately 55,000 birds (MDC 2016a). The Department of Conservation also maintains deer harvesting data, which can be used to provide a general idea of the amount of deer that may be present in an area. In Dallas County, approximately 3,503 deer were harvested during the 2015 – 2016 deer season. In Laclede County, 4,305 deer were harvested; and in Webster County, 2,928 deer were harvested. Simulated statewide deer population values provided by the Department of Conservation are approximately 75% greater than the number harvested statewide (MDC 2016b).

Due to the lack of watershed specific data about the potential bacteria contributions from wildlife, no estimation on the significance of such contributions can be made. For purposes of this TMDL,

[14] The estimated population per septic system is based on the average value of the 12-digit HUC populations per septic system provided by the STEPL online input data server as presented in Table 12 of this report.

wildlife contributions will be considered in the total nonpoint source load as part of the established load allocation. No specific pollutant reductions from wildlife sources are expected to be necessary to achieve the loading targets established in this TMDL and implementation activities should focus on pollutant reductions from anthropogenic sources.

5.2.5 Riparian Corridor Conditions

Riparian corridor conditions have a strong influence on instream water quality. Wooded riparian buffers are a vital functional component of stream ecosystems and are instrumental in the detention, removal and assimilation of pollutants from runoff. Therefore, a stream with good riparian cover is often better able to mitigate the impacts of high pollutant loads than a stream with poor or no riparian cover. Table 13 presents land cover calculations for the riparian corridors within the Upper Niangua River watershed.

Table 13. Land cover in the riparian corridors of the Upper Niangua River watershed

Land Cover Type	***Area***		
	hectares	***acres***	***Percent***
Developed, High Intensity	0.08	0.22	0.00
Developed, Medium Intensity	6.38	15.79	0.07
Developed, Low Intensity	35.72	88.29	0.38
Developed, Open Space	271.43	670.72	2.90
Barren Land	6.11	15.12	0.07
Cultivated Crops	15.56	38.47	0.17
Hay/Pasture	2,729.78	6,745.44	29.21
Forest	5,787.79	14,301.93	61.94
Shrub and Herbaceous	159.11	393.18	1.70
Wetlands	280.69	693.62	3.00
Open Water	51.92	128.32	0.56
Total:	9,344.57	23,091.1	100.00

This analysis of the riparian corridor used the same land cover data provided in Section 2.4 of this document and defined the riparian area as being a 30-meter (100-foot) buffer on each side of all streams in the watershed that are included in the high resolution National Hydrography Dataset.[15] As can be seen in Table 13, most riparian corridors in the watershed are forested. Approximately 29 percent of the riparian area is categorized as hay or pasture and could be used for livestock grazing. Such close proximity of streams to areas used for livestock grazing can increase the risk of bacterial contamination if animals are not excluded from the stream or adequate buffers to reduce stormwater inputs are not maintained. Similarly, streams adjacent to developed urbanized areas may also receive contaminated runoff as described in Section 5.2.2 of this document.

[15] The National Hydrography Dataset is digital surface water data for geographic information systems, or GIS, for use in general mapping and in the analysis of surface-water systems. Available URL: http://nhd.usgs.gov

6. Numeric TMDL Target and Modeling Approach

As noted in Section 3.2 of this document, Missouri's Water Quality Standards include specific numeric *E. coli* water quality criteria for waters designated for whole body contact recreation categories A and B. The *E. coli* concentration of 126 counts/100 mL, which is protective of the category A recreational use, will serve as the numeric target for TMDL development for the Niangua River. The *E. coli* concentration of 206 counts/100mL, which is protective of the category B recreational use, will serve as the numeric target for TMDL development for Dousinbury Creek. The resulting TMDLs will be expressed using load duration curves that depict bacteria loads for all possible flows. The area under the curve is the compliance zone of the waterbody to the applicable criterion. When the geometric mean of all measured loads is located under the load duration curve, then water quality standards are achieved. Although applied as a daily target for the purposes of a TMDL, *E. coli* criteria are expressed as geometric means in the Missouri Water Quality Standards. Fluctuations in instantaneous instream bacteria concentrations are expected and individual bacteria measurements that are greater than the applicable recreational use concentration do not, in and of themselves, indicate a violation of water quality standards.

The load duration curve approach is consistent with the Anacostia Ruling (*Friends of the Earth, Inc., et al v. EPA*, No 05-5010, April 25, 2006) and EPA guidance in response to this ruling (EPA 2006; EPA 2007a). EPA guidance recommends that all TMDLs and associated pollutant allocations be expressed in terms of daily time increments, and suggests that there is flexibility in how these daily increments may be expressed. This guidance indicates that where pollutant loads or water body flows are highly dynamic, it may be appropriate to use a load duration curve approach, provided that such an approach "identifies the allowable daily pollutant load for any given day as a function of the flow occurring on that day" (EPA 2006). In addition, for targets that are expressed as a concentration of a pollutant, it may be appropriate to use a table or graph to express individual daily loads over a range of flows as a product of a water quality criterion, stream flow and a conversion factor (EPA 2006).

The load duration curve approach is also useful in identifying and differentiating between storm-driven and steady-input sources. The load duration approach may be used to provide a visual representation of stream flow conditions under which bacteria criteria exceedances have occurred, to assess critical conditions, and to quantify the level of reduction necessary to meet the surface water quality targets for instream bacteria (Cleland 2002; Cleland 2003). To develop the load duration curves for impaired streams in the Upper Niangua River watershed, flow duration curves were developed using average daily flow data collected from USGS stream gages located in the watershed. Additional discussion about the stream gages and methods used to develop the bacteria load duration curves is presented in Appendix B.

7. Calculating Loading Capacity

A TMDL calculates the loading capacity of a water body and allocates that load among the various pollutant sources in the watershed. The loading capacity is the maximum pollutant load that a water body can assimilate and still meet water quality standards. It is equal to the sum of the wasteload allocation, load allocation and the margin of safety:

$$\text{TMDL} = \text{LC} = \sum\text{WLA} + \sum\text{LA} + \text{MOS}$$

Where LC is the loading capacity, ∑WLA is the sum of the wasteload allocations, ∑LA is the sum of the load allocations, and MOS is the margin of safety.

According to 40 CFR 130.2(i), TMDLs can be expressed in terms of mass per unit time, toxicity or other appropriate measures. For the pathogen impaired streams in the Upper Niangua River watershed, TMDLs are expressed as *E. coli* counts per day using load duration curves. Figures 10 and 11 present the load duration curves for the impaired water bodies. To develop these load duration curves, the numeric TMDL target is multiplied by flow to generate the maximum daily load at different flows.[16] The resulting load duration curves represent the streams' loading capacity and are presented as curves over the range of flows. In each of the following figures, the y-axis describes bacteria loading as counts per day and the x-axis represents the frequency for which a particular flow is met or exceeded. Lower flows are equaled or exceeded more frequently than higher flows. Estimates of instantaneous bacteria loads calculated from the most recent *E. coli* monitoring data used for water quality assessment are plotted as points. These observed loads are presented only to illustrate flow conditions under which excessive bacteria loading may be occurring and were not used in the calculations for loading capacity or allocations. The flow condition ranges and descriptions presented in these figures illustrate general base-flow and surface-runoff conditions consistent with EPA guidance about using load duration curves for TMDL development (EPA 2007b). Tables 14 and 15 provide a summary of the TMDL loading capacities and allocations for selected flow exceedances from the load duration curves. Due to the extremely large numbers associated with bacteria loads, *E. coli* values are presented using scientific notation. Specific allocations for individual sources are presented and discussed in Sections 8 and 9 of this report.

[16] $\boldsymbol{Load}\left(\frac{\text{count}}{\text{time}}\right) = \boldsymbol{Concentration}\left(\frac{\text{count}}{\text{volume}}\right) * \boldsymbol{Flow}\left(\frac{\text{volume}}{\text{time}}\right)$

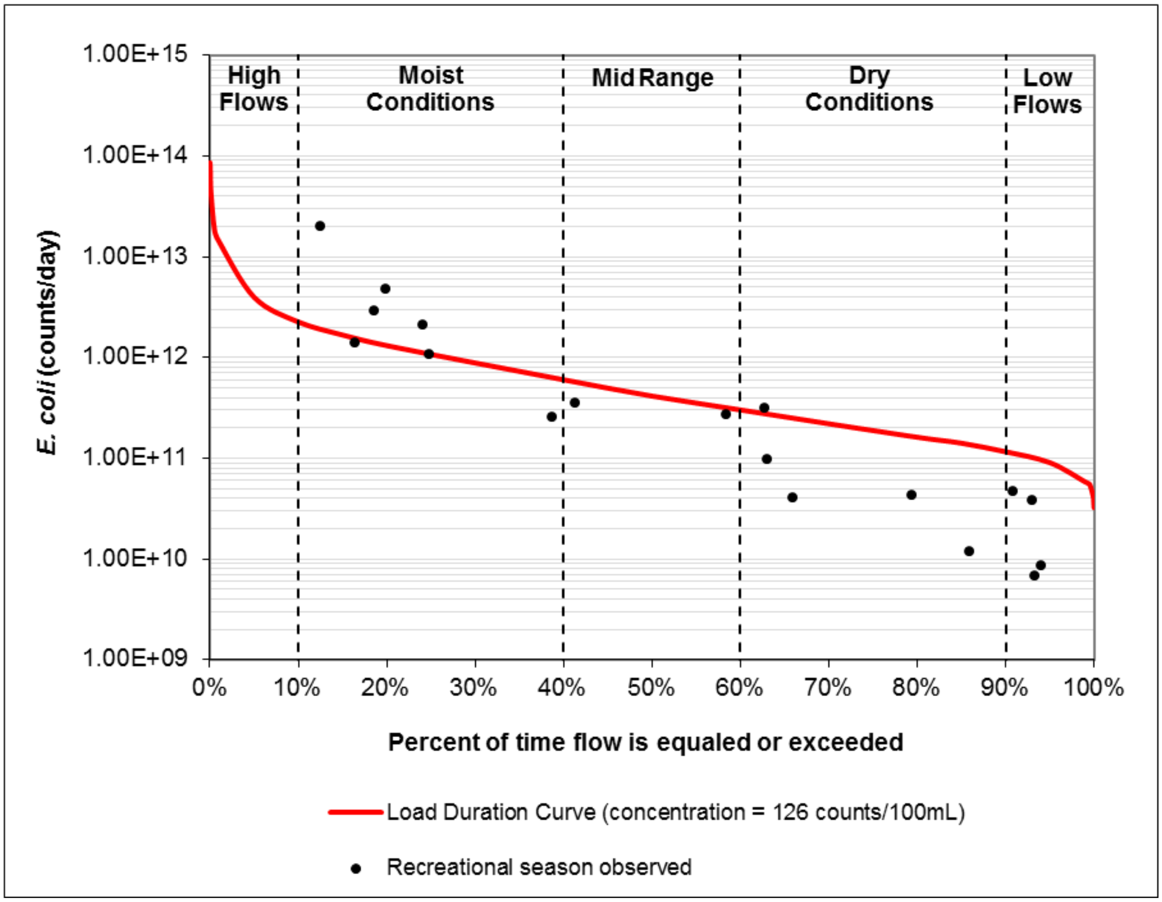

Figure 10. Load duration curve – Niangua River, water body ID no. 1170

Table 14. TMDL and allocation values for the Niangua River at selected flows

Percent of time flow equaled or exceeded	*Flow* m^3/s *(ft^3/s)*	*TMDL (counts/day)*	*∑WLA (counts/day)*	*∑LA (counts/day)*	*MOS (counts/day)*
95	0.83 (29.4)	9.06E+10	8.11E+09	7.35E+10	9.06E+09
75	1.73 (61.2)	1.89E+11	8.11E+09	1.62E+11	1.89E+10
50	3.80 (134.4)	4.14E+11	8.11E+09	3.65E+11	4.14E+10
25	9.90 (349.7)	1.08E+12	8.11E+09	9.62E+11	1.08E+11
5	36.37 (1,284.7)	3.96E+12	8.11E+09	3.56E+12	3.96E+11

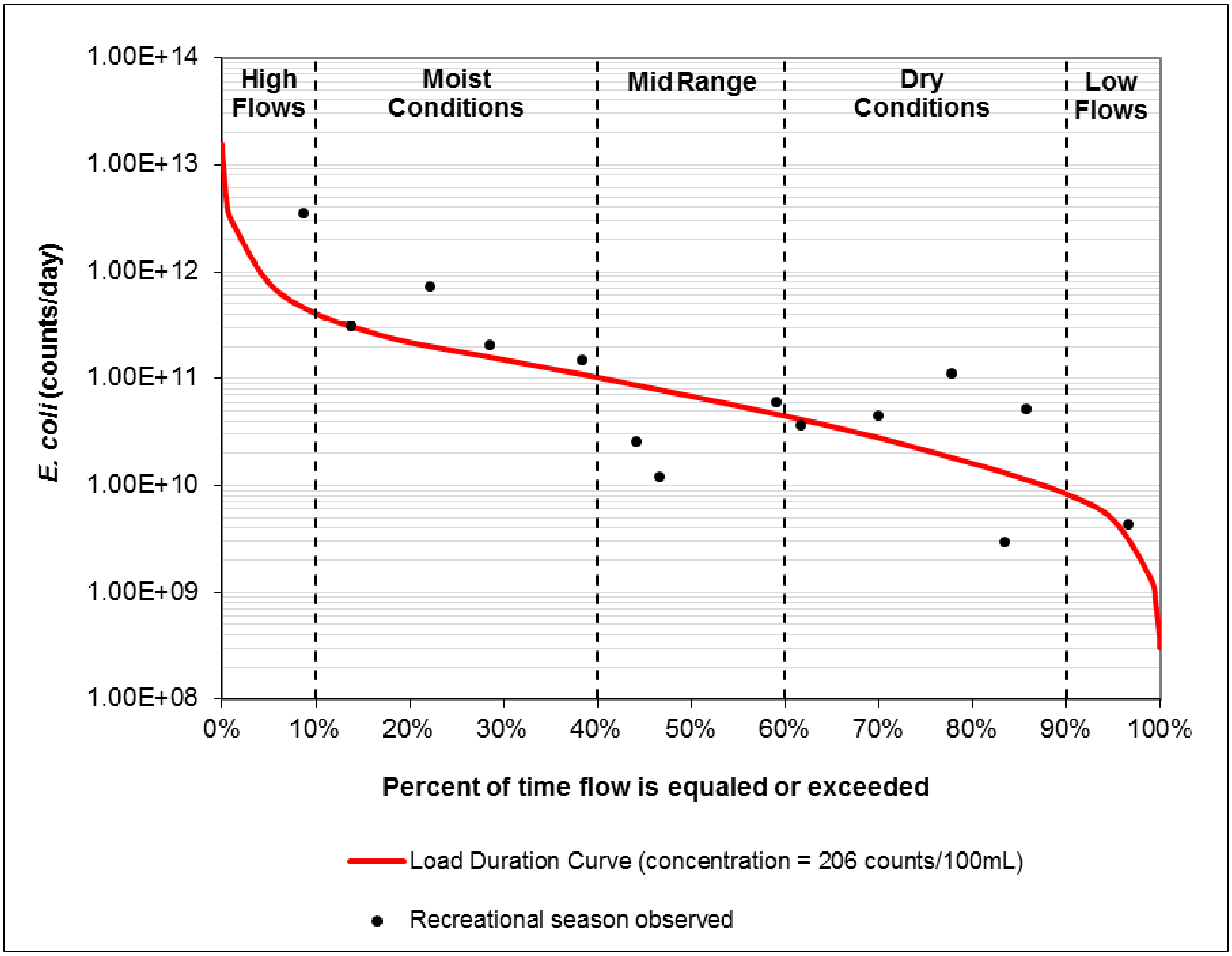

Figure 11. Load duration curve – Dousinbury Creek, water body ID no. 1180

Table 15. TMDL and allocation values for Dousinbury Creek at selected flows

Percent of time flow equaled or exceeded	*Flow m^3/s (ft^3/s)*	*TMDL (counts/day)*	*∑WLA (counts/day)*	*∑LA (counts/day)*	*MOS (counts/day)*
95	0.02 (1.0)	4.76E+09	0	4.29E+09	4.76E+08
75	0.12 (4.3)	2.18E+10	0	1.96E+10	2.18E+09
50	0.38 (13.6)	6.85E+10	0	6.16E+10	6.85E+09
25	1.00 (35.4)	1.78E+11	0	1.61E+11	1.78E+10
5	4.37 (154.4)	7.78E+11	0	7.00E+11	7.78E+10

8. Wasteload Allocation (Allowable Point Source Load)

The wasteload allocation is the allowable amount of the loading capacity that is assigned to existing or future point sources. This section discusses the rationale and approach for assigning wasteload allocations to point sources in the Upper Niangua River watershed as well as considerations given for future sources. Typically, point sources are permitted with limits for a given pollutant that are the most stringent of either technology-based effluent limits or water quality-based effluent limits. Technology-based effluent limits are based upon the expected capability of a treatment method to reduce the pollutant to a certain concentration. Water quality-based effluent limits represent the most stringent concentration of a pollutant that a receiving stream can assimilate without violating applicable water quality standards at a specific location. Effluent limits or other permit conditions must be consistent with the assumptions and requirements of TMDL wasteload allocations per 40 CFR §122.44(d)(1)(vii)(B).

8.1 Municipal and Domestic Wastewater Discharges

The aggregated wasteload allocation for municipal and domestic wastewater dischargers in the Upper Niangua River watershed is 8.11E+09 *E. coli* counts/day as presented in Table 14. This allocation is based on individual facility design flows and the applicable *E. coli* criterion to protect recreational uses in the receiving waters of the effluent discharges. For facilities that discharge into losing streams, the more stringent losing stream *E. coli* criterion was used.[17] The information used to derive this allocation is presented in Table 16. Actual flows that are less than the design flows and available disinfection technologies may allow these facilities to discharge bacteria loads less than those used to calculate the wasteload allocation. The wasteload allocation in this TMDL report does not authorize any facility to discharge bacteria at concentrations that exceed water quality standards, but may serve to accommodate additional facility loading due to population increases or expansions in service area. The wasteload allocation for this TMDL is applicable at all flows.

Table 16. Data for calculation of aggregate WLA for municipal and domestic wastewater dischargers

Permit No.	***Facility Name***	***E. coli Concentration (counts/100mL)***	***WLA (counts/day)***
MO-0031674	Conway WWTF	206	6.44E+08
MO-0109746	Fountain Plaza Mobile Home Park	206	5.47E+07
MO-0052051	Gaslight Village Mobile Home Park	206	3.91E+07
MO-0040843	Marshfield WWTF	126	7.17E+09
MO-0125865	Merritt's Campground	206	5.86E+07
MO-0056227	MoDOT I-44 Conway Welcome Center	126	1.05E+08
MO-0125717	Shady Lane WWTF	126	1.72E+07
MO-0135623	Sho-Me Power WWTF	126	2.39E+07
		WLA =	**8.11E+09**

[17] Missouri's Water Quality Standards at 10 CSR 20-7.031(5)(C) states that the *E. coli* count shall not exceed 126 counts/100 mL of water at any time in losing streams.

In addition to authorized discharges from municipal wastewater treatment facilities, areas serviced by sanitary sewer systems risk bacteria contributions due to accidental overflows. As mentioned in Section 5.1.1 of this document, sanitary sewer overflows are unpermitted discharges and are not authorized under the Clean Water Act. For this reason, sanitary sewer overflows in the Upper Niangua River watershed are assigned a wasteload allocation of zero at all flows.

8.2 Site-Specific Permitted Industrial and Non-Domestic Wastewater Facilities

There are no site-specific permitted industrial and non-domestic wastewater facilities in the Upper Niangua River watershed. These types of facilities are not expected to significantly contribute to existing bacteria loads. For these reasons, site-specific permitted industrial and non-domestic wastewater facilities are not assigned a portion of the calculated wasteload allocation.

8.3 Municipal Separate Storm Sewer System (MS4) Permits

Currently there are no regulated MS4s in the Upper Niangua River watershed and any *E. coli* contributions from urban stormwater runoff are included in the nonpoint source load allocation. If at any time an existing MS4 is required to be permitted, then the appropriate portion of the load allocation may be assigned as a wasteload allocation.

8.4 General Wastewater and Stormwater Permits

Activities permitted through general or stormwater permits are not generally expected to contribute significant bacteria loads to surface waters and the department assumes that such activities conducted in compliance with all specified permit conditions, including land applications, monitoring and discharge limitations, will not contribute significant bacteria loads to surface waters. It is expected that compliance with these types of permits will be protective of the applicable designated recreational uses within the watershed. For this reason, these types of facilities are not assigned a specified portion of the calculated loading capacity. Wasteload allocations for these facilities are set at existing permit limits and conditions, which are assumed to be protective of all designated uses and result in bacteria loading at *de minimis* concentrations.

8.5 Illicit Straight Pipe Discharges

Illicit straight pipe discharges are illegal and are not permitted under the Clean Water Act. For this reason, illicit straight pipe discharges are assigned a wasteload allocation of zero and any existing sources of this type must be eliminated.

8.6 Considerations for Future Point Sources

For these TMDLs, no specific portion of the loading capacity is allocated to a reserve capacity. However, the wasteload allocations presented in this TMDL report do not preclude the establishment of future point sources of bacteria in the watershed. Any future point sources should be evaluated against the TMDL and the range of flows, which any additional bacterial loading will affect, as well as any additional requirements associated with antidegradation. Per federal regulations at 40 CFR 122.4(a), no permit may be issued when the conditions of the permit do not provide for compliance with the applicable requirements of the Clean Water Act, or regulations promulgated under the Clean Water Act. Additionally, 40 CFR 122.4(i) states no permit may be issued to a new source or new discharger if the discharge from its construction or operation will cause or contribute to violation of water quality standards. Future general (MO-G) and stormwater (MO-R) permitted activities that do not actively generate bacteria and that operate in full compliance with permit conditions are not

expected to contribute bacteria loads above *de minimis* levels and will not result in loading that exceeds the sum of the TMDL wasteload allocations. New domestic wastewater treatment systems that undergo antidegradation review will be required to disinfect their effluent, and therefore, are not expected to cause or contribute to the impairment. Decommissioning of onsite wastewater treatment systems and home connection to a sewerage system for wastewater treatment will result in net pollutant reductions that are consistent with the goals of this TMDL. Wasteload allocations calculated for existing municipal and domestic wastewater dischargers are based on existing design flows. Use of design flows for calculating wasteload allocations instead of the facilities' actual flows account for future increases in discharge from these facilities. Wasteload allocations between point sources may also be shifted appropriately between individual point sources where pollutant loading has shifted as long as the sum of the wasteload allocations is unchanged. In some instances a potential source may be re-categorized from a nonpoint source to a point source (e.g., newly designated MS4s or other permitted stormwater). If such a source's magnitude, character, and location remain unchanged, then the appropriate portion of the load allocation may be assigned as a wasteload allocation (EPA 2012).

9. Load Allocation (Nonpoint Source Load)

The load allocation is the amount of the pollutant load that is assigned to nonpoint sources and includes all existing and future nonpoint sources, as well as natural background contributions (40 CFR § 130.2(g)). Load allocations for these TMDLs have been calculated as the remainder of the loading capacity after allocations to the wasteload allocation and margin of safety. These total load allocations are presented in Tables 14 and 15. No portion of these load allocations is assigned to onsite wastewater treatment systems as such systems should not be contributing significant bacteria loads when properly designed and maintained. For this reason, onsite wastewater treatment systems are assigned a load allocation of zero at all flows.

10. Margin of Safety

A margin of safety is required in the TMDL calculation to account for uncertainties in scientific and technical understanding of water quality in natural systems (CWA §303(d)(l)(C) and 40 C.F.R. §130.7(c)(l)). The margin of safety is intended to account for such uncertainties in a conservative manner. Based on EPA guidance, the margin of safety can be achieved through two approaches:

- Explicit - Reserve a portion of the loading capacity as a separate term in the TMDL
- Implicit - Incorporate the margin of safety as part of the critical conditions for the wasteload allocation and the load allocation calculations by making conservative assumptions in the analysis

For these TMDLs, an explicit 10 percent of the loading capacity has been reserved to serve as a margin of safety. Additionally, bacteria decay rates were not applied and the direct recreation-season geometric mean was used for estimating the Clean Water Act required daily loading value. These conservative assumptions serve as an additional implicit margin of safety. Also, calculated wasteload allocations to permitted domestic wastewater dischargers are likely to never be realized as available disinfection technologies work to eliminate nearly all present pathogens (target = 0 counts/100mL), rather than targeting a specific water quality criterion, resulting in very low *E. coli* concentrations.

11. Seasonal Variation

Federal regulations at 40 CFR §130.7(c)(1) require that TMDLs take into consideration seasonal variation in applicable standards. Missouri's water quality criteria for the protection of recreational uses are applicable only during the recreational season. However, the load duration curves for these TMDLs represent streamflow under all conditions and were developed using numerous years of flow data collected during all seasons. For this reason, the *E. coli* targets and allocations found in this TMDL report will be protective throughout the recreational season as well as during flow conditions associated with storm-driven events, such as those associated with seasonal rain patterns, when bacteria loading is more likely. The advantage of a load duration curve approach is that all flow conditions are considered and the constraints associated with using a single-flow critical condition are avoided.

12. Monitoring Plans

The department is planning to conduct bacteria monitoring for the Niangua River and Dousinbury Creek during the 2017 and 2018 recreational seasons. Five samples from each water body will be collected during each recreational season. Quality assurance project plans, or QAPPs, to conduct this monitoring have been finalized and are on file with the department. Results of this scheduled monitoring will be used for determinations of water quality standards attainment or continued impairment as part of the department's biennial water quality assessments required for Clean Water Act 305(b) and 303(d) reporting. The data derived from this monitoring may also be used for adjusting pollutant reduction goals and informing implementation activities.

Additional post-TMDL monitoring is often scheduled and carried out by the department approximately three years after the approval of the TMDL or in a reasonable time period following completion of permit compliance schedules and the application of new effluent limits. The department will also routinely examine quality-assured water quality data collected by other local, state and federal entities in order to assess the effectiveness of TMDL implementation. In addition, certain quality-assured data collected by universities, municipalities, private companies and volunteer groups may potentially be considered for monitoring water quality following TMDL implementation.

13. Reasonable Assurance

Section 303(d)(1)(C) of the federal Clean Water Act requires that TMDLs be established at a level necessary to implement applicable water quality standards. As part of the TMDL process, consideration must be given to the assurances that point and nonpoint source allocations will be achieved and water quality standards attained. Where TMDLs are developed for waters impaired by point sources only, reasonable assurance is provided through the NPDES permitting program. Issuance of state operating permits and requiring that effluent and instream monitoring be reported to the department should provide reasonable assurance that instream water quality standards will be met.

Where a TMDL is developed for waters impaired by both point and nonpoint sources, point source wasteload allocations must be stringent enough so that in conjunction with the water body's other loadings (i.e., nonpoint sources) water quality standards are met. This generally occurs when the TMDL's combined nonpoint source load allocations and point source wasteload allocations do not exceed the water quality standards-based loading capacity and there is reasonable assurance that the TMDL's allocations can be achieved. Reasonable assurance that nonpoint sources will meet their

allocated amount in the TMDL is dependent upon the availability and implementation of nonpoint source pollutant reduction plans, controls or BMPs within the watershed. If BMPs or other nonpoint source pollution controls make more stringent load allocations practicable, then wasteload allocations can be made less stringent. Thus, the TMDL process provides for nonpoint source control tradeoffs (40 CFR 130.2(i)). When a demonstration of nonpoint source reasonable assurance is developed and approved for an impaired water body, additional pollutant allocations for point sources may be allowed provided water quality standards are still attained. When a demonstration of nonpoint source reasonable assurance does not exist, or it is determined that nonpoint source pollutant reduction plans, controls or BMPs are not feasible, durable, or will not result in the required load reductions, allocation of greater pollutant loading to point sources cannot occur.

A variety of grants and loans may be available to assist watershed stakeholders with developing and implementing watershed based plans, controls and practices to meet the required wasteload and load allocations in the TMDL and demonstrate reasonable assurance. Information regarding potential funding sources and implementation actions addressing pollutant sources in the watershed can be found in the Upper Niangua River Watershed *E. coli* TMDL Implementation Strategies document at dnr.mo.gov/env/wpp/tmdl/1170-1180-niangua-r-dousinbury-cr-record.htm.

14. Public Participation

EPA regulations at 40 CFR§130.7 require that TMDLs be subject to public review. A 45-day public notice period for this TMDL report is scheduled from Aug. 3, 2017 to Sept. 18, 2017. All comments received during this period and the department's responses to those comments will be made available online.

Groups that directly received notice of the public comment period for this TMDL include, but are not limited to:

- Missouri Clean Water Commission
- Missouri Water Protection Forum
- Missouri Department of Conservation
- County soil and water conservation districts
- County health departments
- County commissions
- Southwest Missouri Council of Governments
- Lake of the Ozarks Council of Local Governments
- University of Missouri Extension
- Missouri Coalition for the Environment
- Stream Teams United
- Stream Team volunteers living in or near the watershed
- Affected permitted entities
- Missouri state legislators representing areas within the watershed.

In addition to those directly contacted, the public notice, this TMDL report and a supplemental implementation strategies document have been posted on the department's TMDL webpage at dnr.mo.gov/env/wpp/tmdl/1170-1180-niangua-r-dousinbury-cr-record.htm, making them available to anyone with access to the Internet.

The department also maintains an email distribution list for notifying subscribers regarding significant TMDL updates or activities, including public notices and comment periods. Those interested in subscribing to TMDL updates may do so by submitting their email address using the online form available at public.govdelivery.com/accounts/MODNR/subscriber/new?topic_id=MODNR_177.

15. Administrative Record and Supporting Documentation

An administrative record for the Upper Niangua River watershed *E. coli* TMDL has been assembled and is being kept on file with the department. It includes any plans, studies, data and calculations on which the TMDL is based, as well as a TMDL implementation strategies document, the public notice announcement, any public comments received and the department's responses to those comments. This information is available upon request to the department at dnr.mo.gov/sunshine-form.htm. Any request for information about this TMDL will be processed in accordance with Missouri's Sunshine Law (Chapter 610, RSMO) and the department's administrative policies and procedures governing Sunshine Law requests. For more information about open record/Sunshine requests, please consult the department's website at dnr.mo.gov/sunshinerequests.htm.

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Appendix A

Recreational Season *E. coli* Data[18]

Table A.1 Niangua River recreational season *E. coli* data

Sampling Organization	*Site Code*	*Site Name*	*Sample Type*	*Date*	*E. coli (count/100ml)*
USGS	1170/13.8	Niangua River near Windyville	Grab	5/17/1994	700.0
USGS	1170/13.8	Niangua River near Windyville	Grab	6/2/1994	35.0
USGS	1170/13.8	Niangua River near Windyville	Grab	6/14/1994	210.0
USGS	1170/13.8	Niangua River near Windyville	Grab	7/12/1994	10.0
USGS	1170/13.8	Niangua River near Windyville	Grab	8/11/1994	190.0
USGS	1170/13.8	Niangua River near Windyville	Grab	9/7/1994	1,800.0
USGS	1170/13.8	Niangua River near Windyville	Grab	10/4/1994	460.0
USGS	1170/13.8	Niangua River near Windyville	Grab	4/3/1995	9.0
USGS	1170/13.8	Niangua River near Windyville	Grab	5/17/1995	720.0
USGS	1170/13.8	Niangua River near Windyville	Grab	6/20/1995	54.0
USGS	1170/13.8	Niangua River near Windyville	Grab	7/12/1995	110.0
USGS	1170/13.8	Niangua River near Windyville	Grab	8/16/1995	98.0
MoDNR	1170/13.8	Niangua River near Windyville	Grab	7/16/2014	139.6
MoDNR	1170/13.8	Niangua River near Windyville	Grab	7/30/2014	53.7
MoDNR	1170/13.8	Niangua River near Windyville	Grab	8/13/2014	11.0
MoDNR	1170/13.8	Niangua River near Windyville	Grab	8/27/2014	8.4
MoDNR	1170/13.8	Niangua River near Windyville	Grab	9/9/2014	11.0
MoDNR	1170/13.8	Niangua River near Windyville	Grab	9/25/2014	47.1
MoDNR	1170/13.8	Niangua River near Windyville	Grab	10/30/2014	32.7
MoDNR	1170/13.8	Niangua River near Windyville	Field duplicate	4/8/2015	209.8
MoDNR	1170/13.8	Niangua River near Windyville	Field duplicate	4/8/2015	260.3
MoDNR	1170/13.8	Niangua River near Windyville	Field duplicate	4/21/2015	73.3
MoDNR	1170/13.8	Niangua River near Windyville	Field duplicate	4/21/2015	79.4
MoDNR	1170/13.8	Niangua River near Windyville	Field duplicate	5/12/2015	95.9
MoDNR	1170/13.8	Niangua River near Windyville	Field duplicate	5/12/2015	116.9
MoDNR	1170/13.8	Niangua River near Windyville	Grab	5/19/2015	19.9
MoDNR	1170/13.8	Niangua River near Windyville	Field duplicate	6/3/2015	290.9
MoDNR	1170/13.8	Niangua River near Windyville	Field duplicate	6/3/2015	231.0
MoDNR	1170/13.8	Niangua River near Windyville	Field duplicate	6/24/2015	104.6
MoDNR	1170/13.8	Niangua River near Windyville	Field duplicate	6/24/2015	115.3
MoDNR	1170/13.8	Niangua River near Windyville	Grab	7/6/2016	456.9
MoDNR	1170/13.8	Niangua River near Windyville	Field duplicate	7/19/2016	93.3
MoDNR	1170/13.8	Niangua River near Windyville	Field duplicate	7/19/2016	152.9
MoDNR	1170/13.8	Niangua River near Windyville	Grab	8/1/2016	1,299.7
MoDNR	1170/13.8	Niangua River near Windyville	Field duplicate	8/25/2016	43.5
MoDNR	1170/13.8	Niangua River near Windyville	Field duplicate	8/25/2016	55.6
MoDNR	1170/13.8	Niangua River near Windyville	Grab	9/13/2016	44.8

[18] Recreational season *E. coli* data were retrieved from the department's Water Quality Assessment Database on May 22, 2017. For calculation purposes, values from field duplicates collected from the same site and on the same date were averaged.

Table A.2 Dousinbury Creek recreational season *E. coli* data

Sampling Organization	***Site Code***	***Site Name***	***Sample Type***	***Date***	***E. coli (count/100ml)***
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	5/5/1994	160.0
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	5/16/1994	340.0
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	5/26/1994	2,200.0
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	6/2/1994	450.0
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	6/9/1994	590.0
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	6/14/1994	200.0
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	6/22/1994	1,200.0
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	6/29/1994	130.0
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	7/12/1994	120.0
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	7/25/1994	470.0
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	8/16/1994	380.0
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	9/1/1994	1,400.0
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	10/4/1994	1,500.0
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	10/31/1994	1,600.0
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	4/3/1995	180.0
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	5/17/1995	33,000.0
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	6/20/1995	60.0
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	7/12/1995	260.0
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	8/16/1995	1,200.0
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	4/3/1996	280.0
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	5/15/1996	1,600.0
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	6/27/1996	330.0
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	7/24/1996	920.0
USGS	1180/0.8	Dousinbury Creek at Highway JJ	Grab	8/19/1996	250.0
MoDNR	1180/0.8	Dousinbury Creek at Highway JJ	Grab	7/6/2016	727.0
MoDNR	1180/0.8	Dousinbury Creek at Highway JJ	Field duplicate	7/19/2016	206.4
MoDNR	1180/0.8	Dousinbury Creek at Highway JJ	Field duplicate	7/19/2016	328.2
MoDNR	1180/0.8	Dousinbury Creek at Highway JJ	Grab	8/1/2016	201.4
MoDNR	1180/0.8	Dousinbury Creek at Highway JJ	Grab	8/25/2016	30.9
MoDNR	1180/0.8	Dousinbury Creek at Highway JJ	Grab	9/13/2016	45.7

Appendix B

Development of Bacteria Load Duration Curves

Overview

The load duration curve approach was used to develop total maximum daily loads, or TMDLs, for the impaired water body segments in the Upper Niangua River watershed. The load duration curve method allows for characterizing water quality concentrations (or water quality data) at different flow regimes and estimating the load allocations and wasteload allocations for each impaired segment. This method also provides a visual display of the relationship between stream flow and loading capacity. Using the duration curve framework, allowable loadings are easily presented.

Methodology

Using a load duration curve method requires a long-term time series of daily flows, numeric water quality targets, and bacteria data from the impaired streams. Bacteria data from the impaired segments, along with the flow estimates for the same date, are plotted along with the load duration curve to assess when the water quality target may have been exceeded.

To develop a load duration curve, the average daily flow data from a gage or multiple gages that are representative of the impaired reach are used. The flow record should be of sufficient length to be able to calculate percentiles of flow. If a flow record for an impaired stream is not available, then a synthetic flow record is needed. For the Niangua River TMDL, flow records from July 24, 1991 to May 24, 2017 collected by USGS stream gage 06923250 on the Niangua River at Windyville were used. For the Dousinbury Creek TMDL, flow records from April 8, 1993 to Sept. 29, 1997 collected by USGS stream gage 06923150 on Dousinbury Creek at Highway JJ near Wall Street were used along with estimated flows based on a regression of the two gages in order to develop a flow record from 1991 to 2017. This regression analysis is presented in Figure B1.

The modeling approach assumes that discharge at the outlet of the impaired watersheds are proportional to the discharge from the USGS gage stations. Therefore, average daily flow values were corrected based on the proportion of the area draining to the impaired watershed to that draining to the flow gage (Tables B1 and B2). The developed flow duration curves for the impaired water body segments are presented in Figures B2 and B3. These flows in units of ft^3/second are then multiplied by the applicable water quality target (126 counts/100 mL or 206 counts/100 mL) and a conversion factor of 24,465,715 in order to generate the allowable load in units of counts/day.[19] Despite the varying load, the targeted concentration is constant at all flow percentiles and reflects the static nature of the water quality standards.

[19] $Load\ \left(\frac{\text{count}}{\text{day}}\right) = \left[Target\left(\frac{\text{count}}{\text{100ml}}\right)\right] * \left[Flow\ \left(\frac{feet^3}{s}\right)\right] * [Conversion\ Factor]$

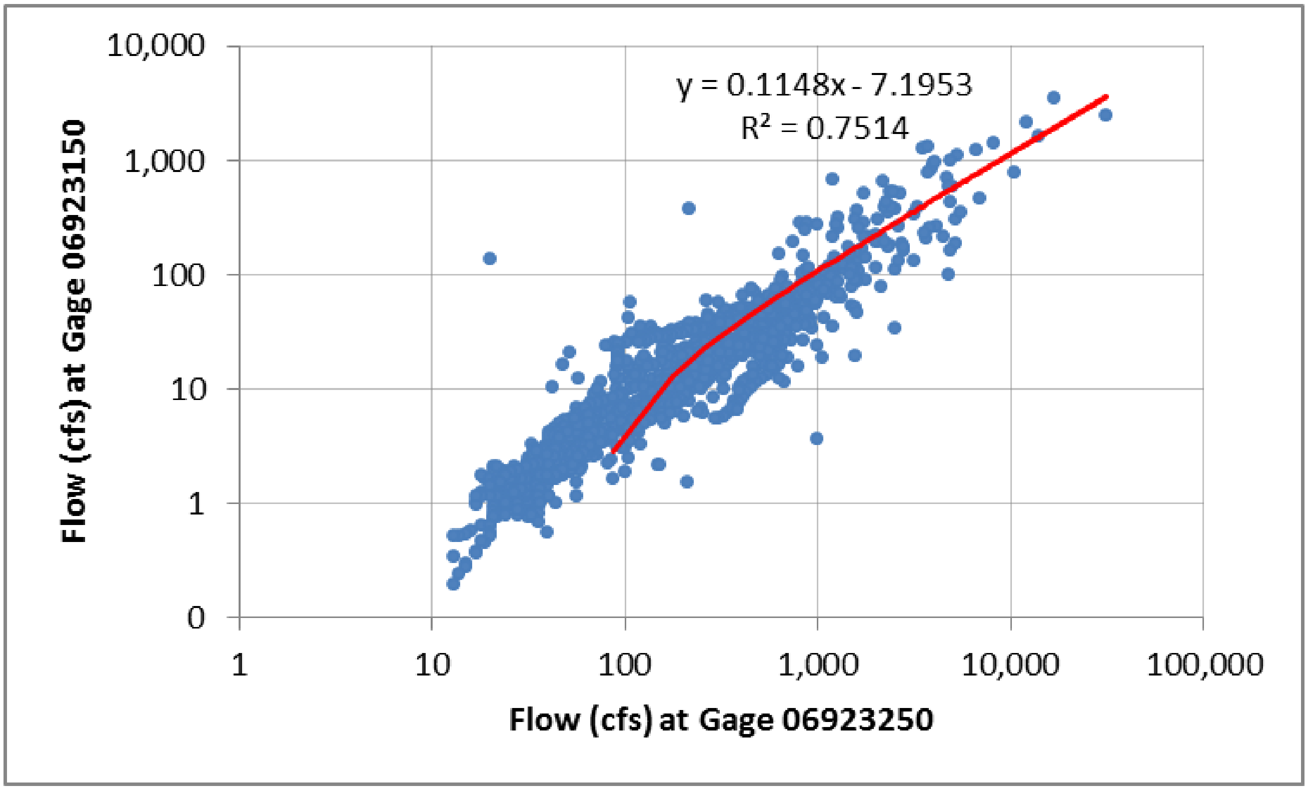

Figure B1. Regression analysis used to estimate flows for Dousinbury Creek

Table B1. Information used for developing area corrected flow for the Niangua River

Location:	USGS 06923250	WBID 1170
Drainage Area:	976.4 km^2 (377 mi^2)	1,025.6 km^2 (396 mi^2)
Correction Factor:	--	1.05

Table B2. Information used for developing area corrected flow for Dousinbury Creek

Location:	USGS 06923150	WBID 1180
Drainage Area:	105.4 km^2 (40.7 mi^2)	108.7 km^2 (42.0 mi^2)
Correction Factor:	--	1.03

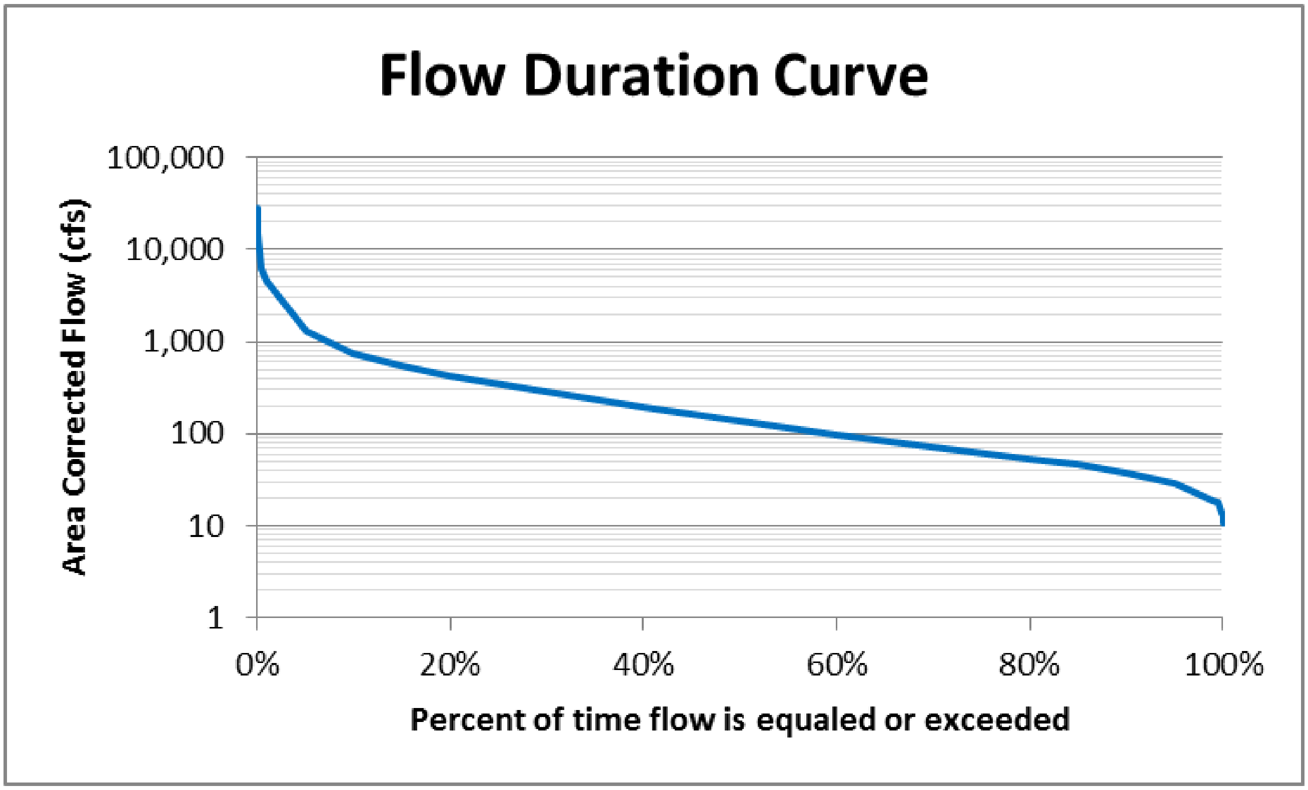

Figure B2. Niangua River flow duration curve

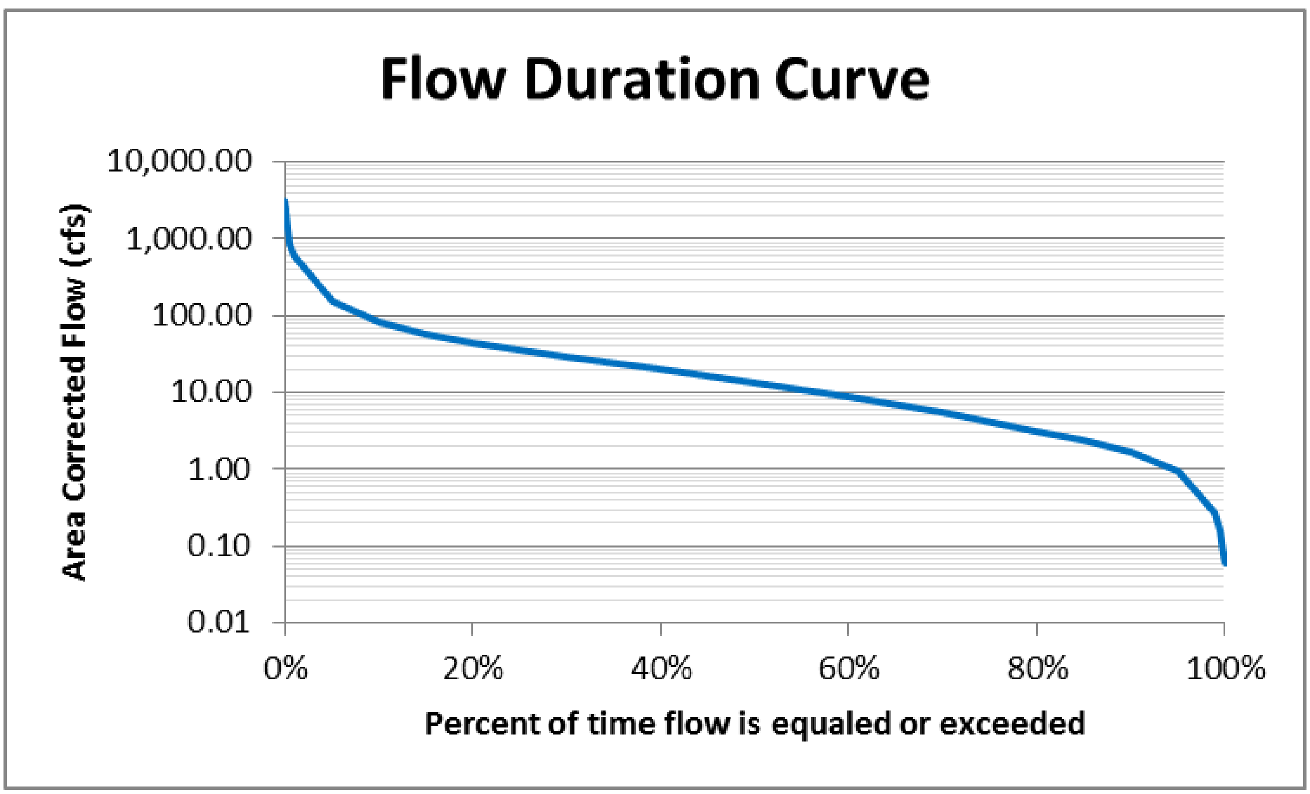

Figure B3. Dousinbury Creek flow duration curve